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Bringing Reality into the Information Space

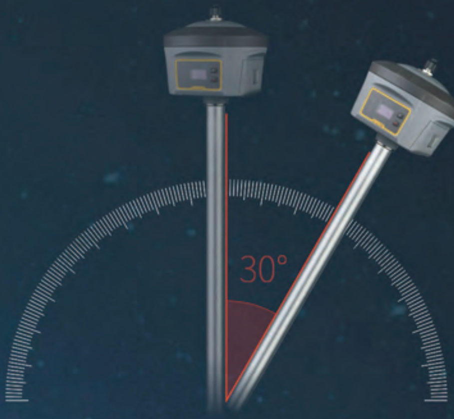
Interview with Dr Bernd-Dietmar Becker, FARO

PUBLIC PARTICIPATION USING 3D CITY MODELS

DIGITAL IMAGE MATCHING FOR EASY 3D MODELLING

GROWING USE OF OBLIQUE IMAGERY BY MUNICIPALITIES

SOUTH
Target your success



GALAXY G6
Intelligent Inertial RTK

- Linux operating system
- Attractive OLED display
- WIFI hotspot & connection
- Radio router
- Electronic bubble correct
- Tilt Compensation
- NFC(Near Field Communication) function
- Positioning rate is up to 50Hz
- Rinex storage support
- Complete NTRIP Caster
- 8GB SSD storage
- OTG host

GALAXY G1
Intelligent Inertial RTK

- Magnesium alloy housing
- Innovative structure design
- 12.9cm × 11.2cm dimension, compact & lightweight
- Full satellite constellations support
- Electronic bubble correct
- Tilt compensation
- NFC(Near Field Communication) function
- Advanced datalink module
- Powerful new Bluetooth module
- Cloud service

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The image on this month's front cover shows the *USS Constitution*, a wooden-hulled, three-masted heavy frigate of the United States Navy, launched in 1797. The photo shows the ship being digitally scanned using Lidar technology. In view of its size, 12 focal spheres were placed around the outside of the ship; the FARO Focus3D laser scanner picks up the points during the scan and creates digital data. (Courtesy: Pete Kelsey, Autodesk)

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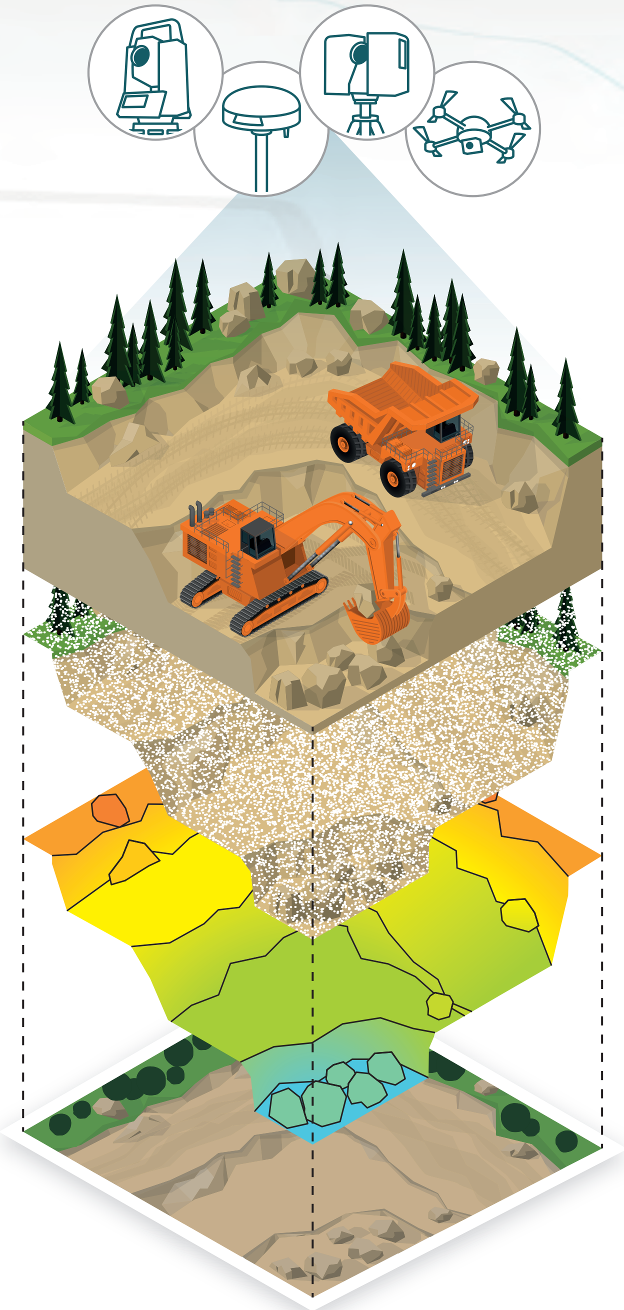

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- Calculate profiles that monitor progress
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Big Data Challenges

The growing world population and the increasing percentage of people living in cities and urban sprawls are causing many problems – or 'challenges', if you prefer that term. One of the biggest issues is, of course, climate change. The Earth's citizens are using up the planet's resources to such an intensive extent that landscapes are changing, rainforests are disappearing, coastal zones are becoming disaster-prone, species are becoming extinct and temperatures are on the rise. Large parts of the globe are becoming inhabitable and people are being forced to migrate in search of better living conditions. This is an undeniable truth, and an "inconvenient" one (to quote a former vice-president of a world-leading country that is now denying this very change – probably because it really is inconvenient). The editorial focus of this issue of *GIM International* is on big data, or more specifically big geospatial data. Big geospatial data is of major importance in gaining a better understanding of how we are harming our planet. Moreover, big geospatial data will be a major factor in policies aimed at stopping climate change and averting other consequences of our ever-growing, fossil energy-slurping and resource-consuming economies. Big data is acquired through satellites, sensors, crowdsourcing, the Internet of Things (IoT) and from many other sources. If any of that data contains a spatial component it can rightfully be called big geospatial data, in which case it automatically falls within our domain. Much of this data is available as open and not-so-open datasets. It can be challenging enough to extract the right insights from the data, let alone to verify its quality. This requires highly skilled data analysts, preferably with a geospatial background. However, such experts are in short supply. More often than not, data scientists don't have a geospatial background and therefore find it difficult to judge the reliability of the data or to identify flaws in it. Should we educate them? Or should we instead fix the loopholes in data acquisition to make all data reliable? Privacy protection is another matter the geospatial data-gatherers have to think about in their discussions of the future. We all know that the internet giants are gathering huge amounts of – mostly geolocated – data about almost all online-active individuals. Is that data – e.g. where I have been, with whom, at what time, buying what with which credit card – safe in the hands of those companies? And if not, what could the geospatial sector offer as an alternative? One final question (for now at least): have we thought about the disintermediation trend? The likes of Uber, Amazon and AirBnB are making former intermediates such as taxi companies, bookstores and travel agencies redundant. Which model could shake up the world of the geolocation monopolists such as mapping agencies and cadastres? Is the big disruptor here blockchain, which automatically registers every transaction between buyers and sellers without intermediation of any kind? Again, how is the geospatial sector preparing for these developments, and have geospatial experts thought about the consequences of it all? Because things will undoubtedly change sooner or later, and more likely sooner rather than later. The future may be bright…if we are able to turn it in our favour.

▲ *Durk Haarsma, publishing director.*

Drones – a Flawed Revolution?

I recently came out of my house to find the crumpled remains of a small drone outside my kitchen window. It had struck the crest of my roof before tumbling to Earth some 10m below. I had to pay 325 euros to have the 17 broken tiles fixed. Nowhere on the drone was there any indication of the owner's identity to help me exact retribution. A few days later I observed a drone skimming just a couple of metres over the heads of the 2,000 or so people at our local village fete. The dangers of such thoughtless or inept operations are obvious. Such dangers are, however, miniscule compared with the many near-misses between commercial aircraft and drones in the vicinity of airports.

On the plus side, unmanned aerial vehicles (UAVs) of various sizes and specifications have already transformed the collection of much data, with users ranging from hobbyists to professional land surveyors and many others. At the extreme, large-scale UAVs controlled by military staff have been used to 'eliminate' terrorist suspects. There is considerable interest in new applications, including the possible delivery of goods; in fact, there have been a number of cases of drugs and mobile phones being 'delivered' to prisoners in jails.

All of this is typical of the impact of any revolutionary new technology: not all the applications are beneficial or anticipated. In many cases, the industry is well aware of what needs to be done to enhance safer and wider drone use. Thus even some relatively low-cost drones can now return to base autonomously when they go beyond the line of sight.

▲ *David Rhind.*

But understandably we are entering the era of drone regulation. There is much talk about UAV traffic management systems, user certification and the preservation of privacy (however unlikely that seems). What we actually need is a universal, effective and low-bureaucracy approach to regulation.

Given that, we should welcome the opening on 12 May 2017 of the European Aviation Safety Agency (EASA) consultation on unmanned aircraft system regulation which seeks comments on the proposed regulations by 15 September 2017 (extended from August 15).

The draft EU regulations make no distinction between commercial and non-commercial operations; the inherent risk involved is the key factor. Low risk (open operation category) does not require prior authorisation by the competent authority. Drones in this category need to be under 25kg in weight and must fly no higher than 120m. Specific (medium risk category) requires authorisation before operation which will take account of the mitigation measures in an operational risk assessment. And Certified (high risk category of operations) requires certification of the UAV, a licensed remote pilot and an operator approved by the competent authority.

There is flexibility for individual nations on how they implement some of the regulations, e.g. geofencing. This seems helpful, not least because existing national general liability laws could be used to deal with some serious incidents.

This is important. If any aspect of the EASA proposal seems to you to be misguided, now is the time to respond to the consultation. One last parochial point: irrespective of whether the UK has left the EU by the time the regulations are transposed into national law, it would be wise to adopt the final European scheme.

Leica Geosystems' New 3D Imaging Laser Scanner Available in Europe

The BLK360.

Leica Geosystems has announced that its BLK360 miniaturised 3D imaging laser scanner is now available for reservation within Europe, for delivery in summer. The laser scanner simplifies the collection of as-built reality capture data for work in architecture, design, construction and engineering, among other vertical markets. Anyone who has ever relied on pencil and paper, tape measures or other measuring devices to capture a room's dimensions and images knows that there is always redundancy and missed measurements, said Steven Gross, architectural engineer at Valley Home Improvement. He explained that with the BLK360 those issues disappear. Everything is captured on the first visit, which streamlines the process and saves enormous amounts of time.

▸ **http://bit.ly/2swu7CZ**

Carl Reed Strengthens Spatineo's Board

Carl Reed, former CTO and executive director of the standards programme of Open Geospatial Consortium (OGC), has joined Spatineo as a board member. With Dr Reed's knowledge and connections in the geospatial industry, Spatineo aims to reach its maximum potential in the market of high-quality geospatial data sharing more quickly. Spatineo, a Finland-based leading expert for spatial web services with strong OGC and INSPIRE expertise, was seeking an experienced and forward-looking member for its board. Carl Reed has pioneered geospatial standardisation since 1994, when he saw that standards were needed to enable the geospatial community to grow. Reed joined OGC as CTO in 2001 and has since contributed to multiple geospatial projects and made geospatial information more useable and discoverable.

▸ **http://bit.ly/2sOH2TN**

Carl Reed (right) and Spatineo's Sampo Savolainen.

East View Geospatial Contributes to Machine Learning Technology

East View Geospatial (EVG), a provider of content-rich cartographic products, continues to enhance the accuracy of automated feature identification using its newly developed training datasets in supervised machine learning applications. The impressive early results pertained to automated recognition of building structures in an ongoing pilot project in Papua New Guinea (PNG). Rod Buhrsmith, responsible for business development at EVG, explained that the goal is to create a state-of-the-art process that produces the highest-quality training data available for the users and developers of supervised machine learning technology. In the space of just a few months, significant progress has been made and he expects to push the accuracy even higher. According to Buhrsmith, East View Geospatial continues to seek partners in the GIS and GEOINT ecosystems who are building geospatial machine learning capabilities and need high-quality source data to break through to the next level of big data analytics.

▸ **http://bit.ly/2sRAG6O**

Supervised machine learning results.

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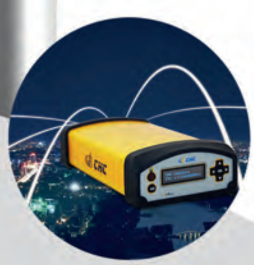


Trimble Acquires NM Group to Strengthen 3D Asset Management Capabilities

NM Group's Caydence 3D environment.

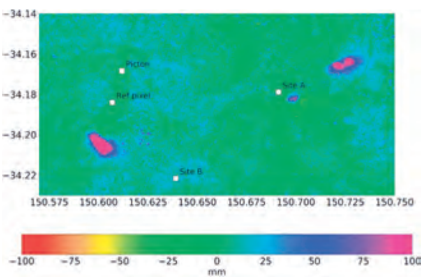
Network Mapping Group (NM Group) has been acquired by Trimble. The purchase will deliver synergies for both companies and provide Trimble access to NM Group's 3D asset management solutions as well as its long experience in delivering electric network and powerline engineering and data modelling services. NM Group is a market-leading provider of data modelling, engineering and 3D asset management solutions for electricity networks. NM Group combines multiple remote sensing techniques with unique data analysis capabilities, including provision of 3D models, engineering assessments and vegetation risk analysis. A key component in providing value to customers is the Caydence 3D visualisation solution, which distributes precise, easy-to-use network information throughout the organisation. Regarding the acquisition, NM Group Chairman David Langworth commented that NM Group has led the way in 3D asset management systems for the power industry, and he is delighted that Trimble has seen this inherent opportunity. Moving forward, the commitment to the NM Group customers remains unchanged and the team will continue to deliver best-in-class solutions and services to the market, Langworth added.

▸ **http://bit.ly/2sSmMQZ**

New Open-source Software Strengthens Satellite Geodesy Capability

Scientists from Geoscience Australia have released new software that will improve the ability to process large, remotely sensed satellite datasets. The new PyRate software is open-source Python software for collating and analysing interferometric synthetic aperture radar (InSAR) displacement time-series data. InSAR is a non-invasive geodetic method that detects changes in the height of the Earth's surface using remotely sensed satellite imagery. This is a highly accurate satellite monitoring technique that uses two or more synthetic aperture radar (SAR) images of an area to identify patterns of surface movement over time. By monitoring movements of the Earth's surface, scientists can improve their understanding of how the Earth's crust changes over time, including changes in elevation caused by larger earthquakes and potential land subsidence caused by human activities such as groundwater and resource extraction.

▸ **http://bit.ly/2sLmR8y**



PyRate.

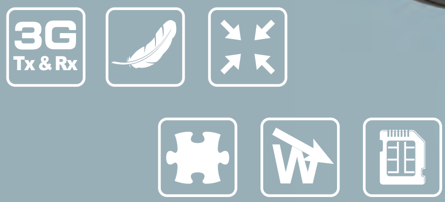
Open Data: Engine for Innovation or Simply Hot Air?

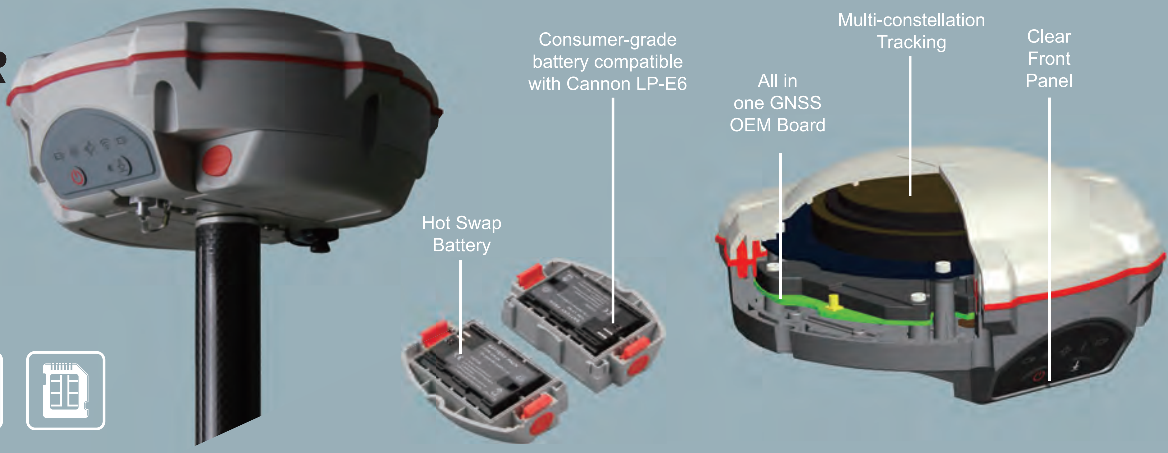
The Intergeo 2017 conference will be hosting what promises to be an exceptionally transparent panel discussion between open data officers. They will be leaving no stone unturned: can open data meet the high expectations vested in it as a driver of innovation and engine of industry? Or does reality seem to fall short? If so, what are the sticking points? And which security risks does transparency pose in an era of cyberattacks and international terrorism? The Intergeo conference offers an exciting insight into the current open data policy of Germany's federal government, its regional administrations and the European Union.

▸ **http://bit.ly/2slZsd5**

Open data: engine for innovation?

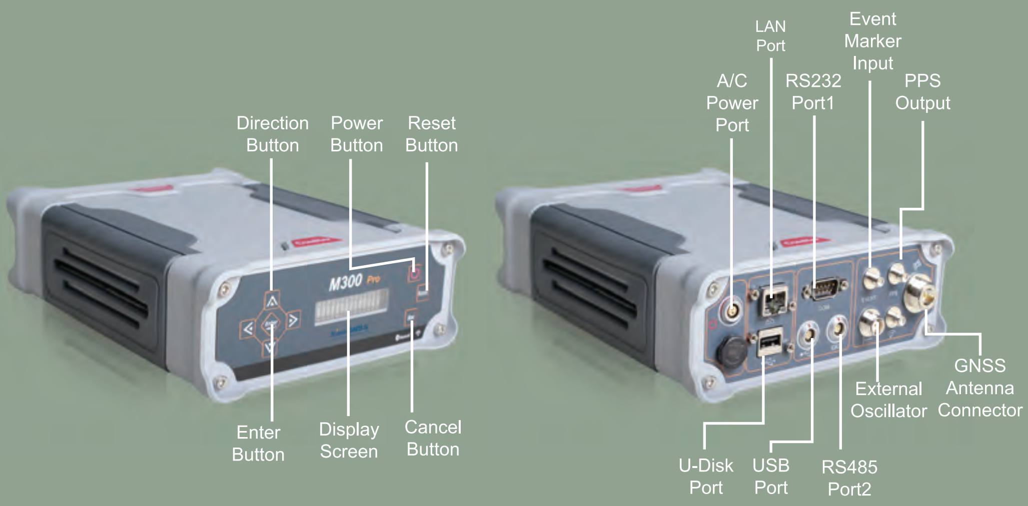
GNSS RECEIVER
T300



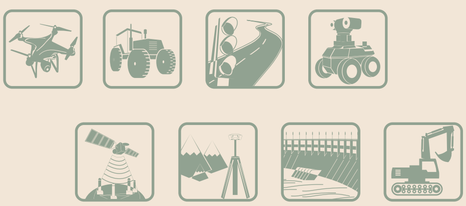


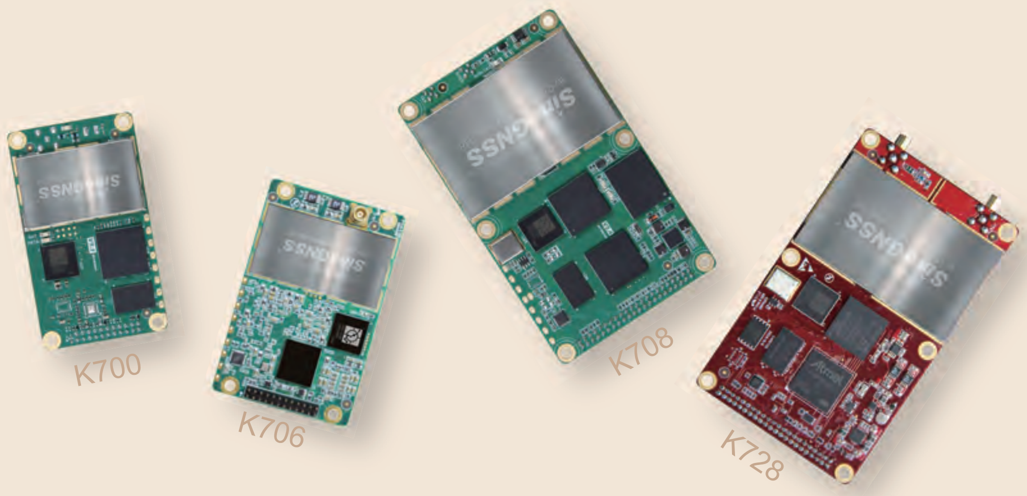
THE NEXT LEVEL RTK

GNSS RECEIVER
M300 Pro



THE NEXT GENERATION CORS RECEIVER





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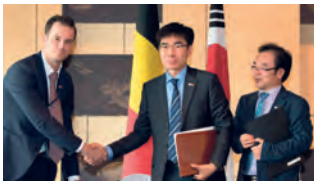
SI Imaging Services and Luciad Sign MoU



The signing ceremony.

SI Imaging Services (SIIS) has signed a Memorandum of Understanding (MoU) with Luciad, a Belgian software provider for worldwide mission-critical operations, and its certified reseller in South Korea, G-Ros, with the goal of offering joint solutions using KOMPSAT data. The signing ceremony took place as part of a week-long business delegation organised by the Belgian Economic Mission to the Republic of Korea from 10-17 June 2017. SIIS is a leading provider of VHR satellite imagery and in particular is a representative of the KOMPSAT series. Luciad is known for its geospatial software platform specialised in the defence, safety & security, aviation, maritime and utilities & logistics sectors. The MoU is set to strengthen the cooperation between South Korea and Belgium. Through this agreement, Luciad will enrich its capacity to offer KOMPSAT's value-added products to customers through the Luciad-based data management, visualisation and analytics system.

▸ http://bit.ly/2sOT6Ev

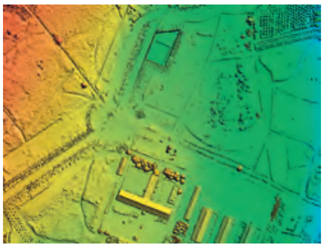
4DMapper Streams 3D Mesh Models

Adelaide 3D model.

4DMapper now supports 3DMesh models in a true geospatial environment, with no software. The tech boom in 3D geospatial, from satellites to UAVs, has seen 3D mesh models as a common deliverable. Beyond the traditional ortho, DTM and point cloud, these 3D models provide a new experience in captured reality, an interactive 3D model of the real world, to inspect, measure and make decisions. The challenge is bringing this rich, powerful data to those that really need it, beyond just the geospatial professionals with specialist software but also to the managers, stakeholders, executives: the decision-makers. In the past, web streaming products for mesh models have been very limited, non-geospatial, constrained by size and resolution, providing a nice visual but lacking sophistication required for the real projects. 4DMapper now streams rendered mesh models in a real geospatial environment. Users can measure and digitise, with accuracy and real-world coordinates and scale, to produce real-world outcomes. Furthermore the size of the dataset is no longer a problem. As the model is tiled and streamed, you don't have to wait for the whole file to load in your browser; you just need the part you're looking at. Not only does this make it fast, but it also means you can stream and share massive files, immediately and with no loss of detail.

▸ http://bit.ly/2rzoBOR

SimActive Helps to Optimise Vineyard Performance with UAVs



Correlator3D DSM.

Canada-based developer of photogrammetry software SimActive has announced that Noveltis, a French company, has been using its Correlator3D software for precision viticulture. Based on multispectral unmanned aerial vehicle (UAV) imagery, mapping products are generated to determine vine health and detect missing plants. SimActive automates the production process for extracting DSMs, DTMs and orthomosaics, said Florian Jeliazovski, project manager at Noveltis. The company greatly improved the detection of vine rows and has been able to provide quantitative and qualitative information to its customers. Noveltis has been building on its expertise in image processing to develop innovative solutions for different applications: Earth observation, environment and sustainable development. The company specialises in the processing, modelling and simulating of environmental data and has extensive expertise in the fields of land surfaces, oceans and atmosphere.

▸ http://bit.ly/2tQRTd8

New Contract to Take EGNOS to Next Level

Paul Verhoef, ESA, and Philippe Blatt, Thales Alenia Space.

ESA has signed a contract with Thales Alenia Space for an upgrade of Europe's EGNOS satellite navigation augmentation system, which underpins the safety-critical use of satellite navigation across the continent. Designed by ESA and being exploited by Europe's GNSS Agency (GSA), the European Geostationary Navigation Overlay Service (EGNOS) improves the precision of US GPS signals over most European territory, while also providing continuous and reliable updates on the integrity of these GPS signals. A network of ground monitoring stations throughout Europe performs an independent measurement of GPS signals so that corrections can be calculated and then passed to users immediately via a trio of geostationary satellites. The result is that the EGNOS-augmented signals are guaranteed to meet the extremely high performance standards set out by the International Civil Aviation Organisation standard, adapted for Europe by Eurocontrol, the European Organisation for the Safety of Air Navigation.

▸ **http://bit.ly/2smp6ic**

Airbus Celebrates 10th Anniversary of TerraSAR-X Satellite

Designed to operate for five years, Airbus's synthetic aperture radar (SAR) satellite TerraSAR-X has achieved ten years of flawless operations in orbit providing high-resolution radar images in all weather conditions, 24 hours a day. Developed and constructed by Airbus Defence and Space teams from Friedrichshafen for the German Aerospace Centre (DLR), the satellite orbits at a height of 514km and provides radar imagery to a wide variety of scientific and commercial users. TerraSAR-X has not only achieved double its service life, having orbited the Earth 55,459 times and travelled 2.4 billion kilometres, all while boasting 99.9 percent availability, but it has also delivered an outstanding performance, said Eckard Settelmeyer, head of Earth observation, navigation and science at Airbus in Germany.

▸ **http://bit.ly/2sOD8KJ**

Geospatial Big Data

Geospatial has always been considered as big data, both by its own advocates and many others. In fact, I could probably stop writing this column right now as we all collectively nod our heads. We could go one step further and find definitions and examples of big data, extremely large datasets and computational analytics. These terms will be familiar to anyone who has worked in GIS. It is not that long ago that big data was only a reflection of volume. For example, Ordnance Survey data was reported as being the largest (Oracle) spatial database. As a representation of the entire visible landscape of Great Britain it certainly contains data on many features and is big by anyone's standards. However, whilst significant and vital for the UK economy, in its current form it is a masterpiece of data collection, storage and delivery. It is not 'big data' as we now define it, but rather – like other geospatial datasets – it is a piece of the picture.

If we are discussing geospatial big data we have to think more broadly and consider 'all' data. The important principle is not how you manage ever-increasing amounts of data in your silos; instead, it's more a matter of how you enable it to be linked to other data. With more and more satellite-based and sensed data becoming available, the data stores that we have built up are increasingly looking small and isolated. In fact, with the ever-increasing volumes of geospatial data, it has become apparent that current geospatial algorithms are not able to scale up so we need to research new ways of creating scalable ones.

Geospatial is merely one part of a much more ubiquitous data ecosystem. Let's take a look at the recent Manchester CityVerve project as a blueprint for smart cities. It needs not only geospatial data, but also many other types of data to provide everything from improved transport and healthcare to retail analytics and emergency-responder positioning. In many ways, big data can be seen as an umbrella term for a massive paradigm shift away from data collection/data delivery pipelines towards a knowledge-sharing environment – enabling the discovery of information through links and relationships. That's why knowledge bases such as Google's Knowledge Graph seem to be emerging in strength. These may be interpreted as evolving from linked data, but they provide a much more fluid knowledge repository without being rigidly built around a triple store.

Many have touched on the opportunities and challenges, but it is clear that geospatial big data is rapidly evolving towards data sharing as the industry responds by extending product ranges and capabilities. The traditional geospatial warehouse is being extended to support structured and unstructured data. Tools for geospatial big data analytics are emerging, such as visualisation, proactive location intelligence and data mining analysis. A key opportunity will be for the support of a geospatial big data service platform to complement the emerging 'Big Data as a Service'. This is not a winner-takes-all situation; this is how the geospatial industry can play the key role in underpinning big data.

Ian Holt has worked on a number of high-profile geospatial data and service implementations around the world, recently at Ordnance Survey and now as CTO at SplashMaps. He advocates the use of open technologies and standards to facilitate interoperable services. Ian volunteers for MapAction, providing services to help support humanitarian relief efforts.

Ian Holt.

INTERVIEW WITH DR BERND-DIETMAR BECKER, CHIEF TECHNOLOGY STRATEGIST AND EVANGELIST, FARO

Bringing Reality into the **Information Space**

FARO is known as a trusted source of high-precision 3D measurement, imaging and visualisation technology. In the surveying and mapping field, the company is particularly well known for its laser scanning solutions. *GIM International's* Wim van Wegen recently met with Dr Bernd-Dietmar Becker, chief technology strategist and head of FARO Labs (the company's research and innovation department) to discuss what we can expect from laser scanning and its role as key reality capturing technology in the years ahead.

You recently announced that you have divided your business into six vertical sales and product management business units. What is the strategy behind this?

We want to be closer to our customers and our industries, and we want to be more solution-oriented. This means we want to start with the customer problem, understand it completely and then deliver a solution that solves that customer problem. The end markets are described in the verticals, i.e. Factory Metrology, Product Design, Construction BIM-CIM, Public Safety Forensics and 3D Solutions. One good example is our market-leading laser scanner; it will work in all of these markets. However, the software often has to be specific, which is why we acquired two software companies in the Public Safety Forensic space: ARAS 360 and CAD Zone. We have now created specific software systems which use the same hardware (laser scanners) but deliver specific features and solutions relevant to the specific needs of a crime scene investigator or crash reconstructionist. We acquired another company, Kubit, which is focused on the construction space. Thanks to its diverse plug-ins to Autodesk products, we now have much better access to the Autodesk universe and customers like architects. So we derive the needs for the hardware products from the verticals and, if possible, we create one product – like the laser scanner – which is good for many verticals. We also create new products, like the handheld laser scanner, which will respond to a particular vertical's specific needs, e.g. forensics or product

design, based on our analysis of that vertical's profile and potential market success.

In addition to the laser scanning itself, it's also important to process, visualise and store the data. Which solutions do you offer for those aspects?

In terms of processing, we have a pretty audacious strategic goal of being in and out of a site 10 times faster than today, so instead of taking two weeks we want to take just one day. We're moving in this direction stepwise. As a first step, how can our customer capture 3D data faster? We believe the indoor mobile mapping system is the right solution. There are already some solutions with handheld systems, but we think the quality is sub-standard and they are not that cheap either. So we are working on a faster capturing solution. Secondly, processing is becoming much faster. FARO Labs has developed the FARO Scan Localiser which constantly performs 2D mapping based on a SLAM algorithm during the scanning project. The Scan Localizer knows where the scan has been taken as well as the orientation. Then the laser scan data is 'stitched together' automatically as the scanner moves forward. You can immediately see if you've forgotten something, which happens often – a washroom or a storage room, for example. You can immediately check the map to make sure you really have every scan registered. With our automatic post-processing software you can still optimise the accuracy, but you'll also immediately see the 2D map and all the scans which are registered in the box. We are working to simplify the software for specific industries such as architecture, construction or forensics with the new FARO Scene, task-oriented software. Many people don't want the complexity of the whole platform, they just want to get results – and fast!

In terms of data storage, way back in 2003 we did a huge project for BMW in Leipzig which involved 3,500 scans to capture the whole plant. We actually managed to send all that data via the internet to Slovakia to get it modelled into MicroStation. So, yes, data is a topic to some extent, but today as storage is becoming so much cheaper and the internet much faster it is less and less of a problem. Of course we're also creating more data – we have now HDR colour and 165 megapixels colour per scan – but at some point of data density it is good enough and it will stop. Take Apple's retina display; personally, as a human being, I don't need more pixels on my display now, I don't need four times retina. So the user's need defines the limit. Therefore I don't see that the data volume will continue rising forever. At the same time, the general bandwidth and the general need for high-volume data is increasing so the solution will overtake the problem. Lastly, we launched our WebShare Cloud system many years ago to bring the data to the cloud, as an Amazon web service. So you can store all the data in the cloud and then access it via the internet. We can now achieve much higher-quality visualisations in the cloud and ultimately everyone will work in the cloud only; there will be no local processing anymore. This means you have the full power and the parallel processing of the cloud, which also is inexpensive. Whether you run one computer for 10,000 seconds or 10,000 computers for one second, the cost is roughly the same. But if you can put things in parallel, which is possible here in many ways, you achieve much faster processing and the storage is pretty cheap too.

Many of your customers are in the construction sector, where building information systems are gaining in importance. Which opportunities does this open up for laser scanner vendors?

Many opportunities! As you know we bring reality into the information space, and the more IT systems someone has the better that is for us, since they need somebody who is delivering content. I relate the CAD system to the time of Rembrandt, when paintings were done by hand. But nowadays we have photo cameras, which means we can create realistic data very easily, quickly and reliably. The CAD system will only be used for new designs; people will scan what they have and model what they want to do in the future – the stuff that they don't have. BIM alone won't be enough; BIM needs a huge point-cloud entry point. And that's actually gradually happening: we're connecting to the Autodesk tools, via our team in Dresden for example. The automotive industry is also using MicroStation, which has a point cloud entry point. It is also embedded into Siemens NX – the Siemens simulation system Plant Simulation and Process Simulate. The scanned points are actually the most real and thus reliable data – they are the 'photograph', if you like. Any subsequent changes are deviations. Ideally, the BIM systems should be able to take in point clouds directly. That's a great thing for the laser scanning industry, and especially for the service providers, since people who create content are needed. Everything is about productivity: about becoming much cheaper and faster, that's the reality. Only the new designs need a Picasso or Rembrandt mindset!

What's the geographical distribution of your global consumer base? In which application domains are FARO scanners mainly used at present and in which areas would you like to become more active in the near future?

Our distribution worldwide is roughly equal across EMEA, the Americas and Asia. Asia has been picking up really well. Regarding the application domains, architecture and construction – our BIM-CIM vertical – is our biggest laser scanning industry accounting for roughly 50%. Forensics is about 25% and growing very fast. The rest is product scanning: shipbuilding, car manufacturing, aerospace, etc. By using the best tools and combining them, we have opened up a new market – product design – which strategically is very interesting. It's a cross-over between our traditional metrology side and our laser scanning side. This vertical covers all kinds of products: cars, ships, scooters, plastics, whatever. It's kind of an overlap between the scan arm used in metrology systems – which is super-accurate but for smaller products – and the larger stuff you can cover with our laser scanners.

FARO laser scanners are also used on mobile mapping systems, using vans and cars as platforms. How do you see the market of mobile laser scanning systems evolving over the coming years?

Mobile mapping is already a productive concept; it's 20 to 50 times faster than stationary scanning. If you want to scan roads and long-distance projects or large objects, then it's a very good option. Of course the accuracy is not as great as in stationary scanning, but if you're scanning many kilometres of roads then there's physically no alternative. Mobile mapping is very logical, yet its success in terms of units sold is still rather small. That's often because the systems are very expensive. Siteco – a FARO partner – is now offering a very good solution which provides a relatively good value-to-cost ratio, but that's still not enough. The costly components are the IMUs, and the professional IMU systems are still too expensive. The question is: do we really need them? There will be technologies such as camera-based stabilisation in the future. Today, even some military drones have been developed which only have a camera. So I think the price will come down further as we research lower-cost inertial systems. The future is a backpack fitted with a scanner – but for lower cost than shown today. When I'm on vacation I can go for a walk, visit a beautiful church or whatever, and then when I get back to the hotel I have captured it all, without even really being aware of the fact that I was scanning. We can compare that to the Kinect system that broke the price barrier at the bottom end of the 3D capturing system market. Now you have a lot of applications which have been developed for consumers but also semi-professionals, and you can do quite a bit with it. There will still be extremely professional products, which make sense for highly accurate solutions, but then there will also be 'take along, walk around and capture' systems.

Staying on the topic of mobile mapping systems, you've already mentioned backpack laser scanners, but there are also handhelds and even laser scanners mounted on unmanned aerial vehicles (UAVs or 'drones'). How is FARO anticipating developments in the drone market?

We already have laser scanners on drones and we've also put a Freestyle in FARO Labs on a drone. This works well, since the Freestyle is developed to move. I am not so thrilled about the future of mounting the traditional FARO laser scanners on a drone, since you need to stabilise it, which today is still expensive, so their time for large-scale application has not come yet. Backpack laser systems are also far too expensive today, we're talking about prices in the range of EUR200,000. Of course they are still in the laboratory phase and the prices must come down over time.

The number of points that can be measured per second is steadily increasing. Where will we be in five years' time?

Actually I don't foresee a dramatic increase in speed, i.e. the point rate – how many points you can capture per second. For example, 20 million points for a short-range scene like a power plant would be perfect, you don't need more; 40 million points is overkill in that context. In a more complex situation 40 million would be ideal, and maybe 200 million would be good for a heritage project. So the question is, how many points do I need and how many scans do I have to make? How many positions do I go through? Then you want to minimise the total capture time. Right now, everyone has got kind of stuck at one million points per second, which I think is good enough. Furthermore, if you increase the point rate you also increase the noise since you have less time to capture photons, so the signal goes down versus noise. There are certainly ways to work on that and it will no doubt improve in the future. And when you take into account the setup time, the start/stop time, moving, registering and so on, then the pure capture time – the point rate – is only a small part of the total time. You can compare it with pixels in cameras. With a chip I can very easily increase the number of pixels if I want to have higher resolution. But then I will need a big enough chip, otherwise I won't have enough light per pixel and there will be too much noise…so I mean, at some point the limit is reached. Overall productivity is more interesting.

Over the past ten to 15 years, a lot of academic research has been conducted to automate the classification of point clouds and to perform 3D modelling semi-automatically. How are these scientific efforts reflected in your products?

They are reflected in the work of FARO Labs and of our Dresden team, the former Kubit team (the former Kubit company, acquired by FARO in 2015), which does the recognition for piping, for walls, for construction and for BIM. They are also reflected through more research in our software team. It is very important because we've calculated that our customers do 10 to the power of 17 points per year. It's really all about retrieving the object information. There are different ways of doing that, e.g. with prismatic objects like pipes or walls, that's what the Dresden team is doing at FARO. We are looking at a solution for factories, construction sites or anywhere you have stand-up parts such as pillars, pipes. So you have a library of known objects and you want to find them in the point cloud so that you can locate them and count them. It's a very important topic, but we're still very much still in the research stage. Nobody in the world has a total solution for this right now.

Which other major developments do you foresee in the coming years that will have a great impact on the laser scanner industry and the geospatial sector as a whole?

For us the top-notch step is ten times more productivity. But other key goals are quality improvement and then the automatic post-processing including object recognition. These are the three major directions for FARO. By the way, in the high-tech industry you never know what will be around the corner! We want to go really fast and adapt quickly to the latest technological opportunities, which is really fun. We need to be very aware of new technological possibilities. The physics are always the same, but when there's a new chip that might enable us to do amazing new things we have to recognise that opportunity immediately. One excellent example is augmented reality, which we're also involved in with our new acquisition MWF (*MWF was acquired at the end of 2016, Ed.*). It enables you to 'go back to reality' and to add all the data and the information you have into that reality; it's especially useful in construction where you can 'see' through the wall to see which pipes are there, it's amazing stuff. This whole development will be an important new force in our industry. ◂

ABOUT DR BERND BECKER

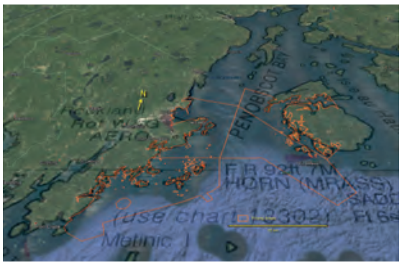
Dr Bernd-Dietmar Becker has been chief technology strategist at FARO Europe since 2012 and he manages the FARO Labs group. He received his PhD in engineering as well as a master's degree in electrical engineering from the University of Stuttgart. He also received an MSc in operations research from Stanford University. He previously worked at the Fraunhofer Institute for Production Automation as a departmental manager and co-founded a factory simulation software company named AESOP GmbH. In 2001 he and his brother founded iQvolution AG, where they invented what today forms the basis of the FARO laser scanner. They sold iQvolution to FARO Technologies in 2005.

INTEGRATING ACTIVE AND PASSIVE SENSORS PROVIDES MAJOR GAINS

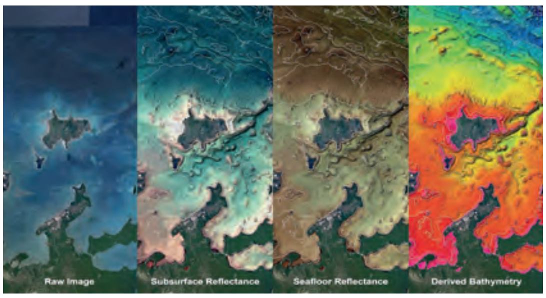
Multi-sensor **Coastal Mapping**

Coastal mapping programmes are quickly becoming a priority for government agencies across the globe. The desire to better define and understand the land/sea interface is based on several interrelated factors, including sea-level rise and its impacts on coastal populations, the growth of and reliance on a blue economy, and the need to maintain critical nearshore habitats in the midst of a changing landscape. Fugro recently tested a multi-sensor approach to balance growing data needs with limited agency budgets.

In support of its hydrographic charting programme, the US National Oceanic and Atmospheric Agency (NOAA) Office of Coast Survey contracted Fugro to provide surveying services in Penobscot Bay, Maine, USA during the summer and autumn months of 2016. The project site encompassed approximately 370 square kilometres in an area characterised by a vibrant lobster fishing industry and high vessel traffic. According to NOAA, most of this area had not been surveyed in more than 60 years and a modern hydrographic survey was needed to update official nautical charts (Figure 1).



▲ *Figure 1, Survey area polygons in Penobscot Bay.*



▲ *Figure 2, Example of EoMap's SDB process correcting raw imagery for atmosphere, water surface and water column conditions.*

The original task order called for data acquisition using multibeam echosounder systems (MBES) mounted on coastal-capable vessels. But given the bay's jagged and rocky shoreline, Fugro considered that a vessel-based survey of the nearshore waters would prove time-consuming and potentially dangerous. While large numbers of submerged rocks were previously marked on existing charts, these vintage datasets were created before the age of full-bottom coverage ensonification. As a result, crews would need to navigate slowly to avoid uncharted hazards. Additionally, the survey was scheduled to take place at the peak of the lobster season, which would further hamper productivity due to the high density of lobster trap rigging and the constant need to avoid entanglement.

ALTERNATIVE APPROACH

In an effort to streamline the survey schedule, reduce the number of required personnel and mitigate property damage and personnel safety, Fugro worked with NOAA to develop a survey plan that would combine vessel-based MBES with airborne Lidar bathymetry (ALB), exploiting the benefits of each sensor system for a faster, more cost-effective programme. The use of ALB was focused on shallow-water areas with a depth of less than 8 metres. This portion of the survey met NOAA charting requirements for least depth information in a safe and efficient manner.

Additionally, reflectance imagery generated from the full-waveform ALB was used to extract natural and manmade coastal features near and above the water surface, allowing for the extrapolation of the mean high water line, used to represent the land boundary on nautical charts. Digital imagery acquired with ALB data collection also produced orthorectified imagery mosaics showing the features and conditions present at the time of survey.

Surveying with MBES and ALB technologies also motivated Fugro to undertake, at no additional cost to the client, the generation of satellite derived bathymetry (SDB) data in concert with partner EoMap GmbH, of Seefeld, Germany. The purpose of the SDB survey was to evaluate its deliverables against fully attributed and quality-assured active sensor data from the ALB and MBES surveys. This represented the latest in a considerable library of real-world data comparisons conducted by Fugro and EoMap to help quantify results in various regional scenarios and develop a strategy for the future employment and utility of the technology.

SDB METHODOLOGY

There are multiple ways to generate bathymetry from multispectral imagery sources. EoMap uses a physics-based method aimed at reconstituting the loss of visible and near-infrared spectral information that occurs when light from the satellite sensor travels through the atmosphere and water. By resolving these light-transfer issues,

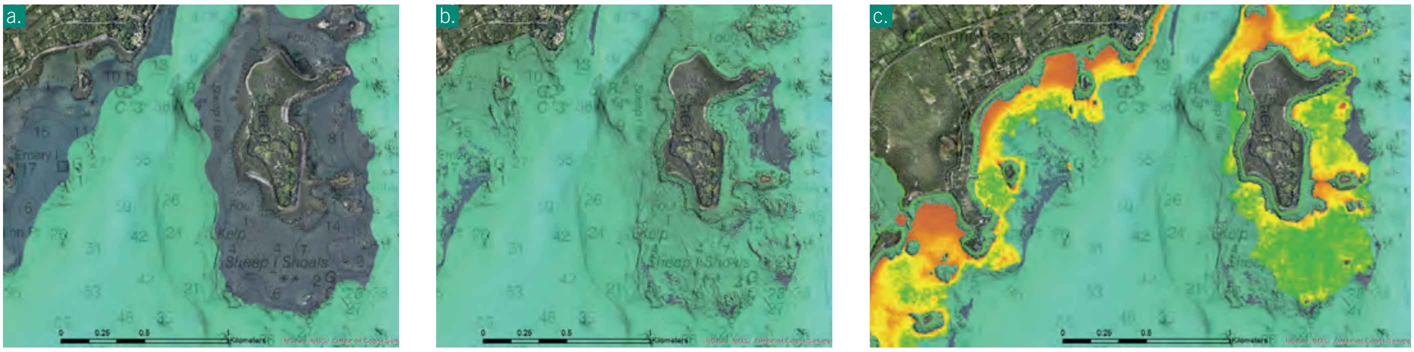


Figure 3, a. MBES coverage; b. MBES and ALB coverage; c. MBES, ALB and highlighted SDB coverage.

EoMap can retrieve the optical properties of the environment to normalise seabed reflectance measurements and provide water depth estimations.

A thoroughly designed workflow of specialised algorithms correct the raw satellite imagery for environmental artefacts – atmospheric aerosol content, land adjacency (high albedo – reflectivity of the Earth's surface) and sun-glitter on the water surface, etc.– and then employ optical models derived for various regional water types. In this way, more accurate water depth estimations and seabed reflectance are produced. This process far exceeds what is possible by using empirical methods or photogrammetric techniques; the former being much degraded due to the reliance on uncorrected raw imagery, and the latter on sheer cost- and time-effectiveness (Figure 2).

RESULTS

The comparison of ALB and SDB was especially useful given the systems' complimentary technical origins. Although ALB is an active sensing technique and SDB is a passive one, both rely on the physical properties of light transmission through the atmospheric and aquatic media. As such, both are able to achieve bathymetric results that overlap to a significant extent, mostly governed by SDB maximum depth detection. Correlation of bathymetric depths on the overlapping areas is one of the main points of interest in the evaluation of SDB methodology: at a minimum, the results achieved by SDB validate its use as a tool for survey project planning, complementing MBES and ALB surveys. Figure 3a, 3b and 3c show a sample area where all three data types overlay.

For NOAA, the primary benefit of SDB is the ability to generate data without the overheads inherent in active sensor surveys. The downside is that the absolute vertical accuracies of water depth extraction algorithms cannot yet satisfy nautical charting requirements in the stand-alone product. Users can, however, take the initial results from SDB and do at least three things:

- Use the data to provide reconnaissance information for follow-on, more efficiently quantifiable MBES and ALB survey techniques (put an otherwise poorly charted area in focus)
- Conduct more discrete, higher resolution surveys of the most critical areas for development or coastal defence/monitoring
- Use active sensor data to refine the original SDB results to create a better defined, integrated product which can start to attain accuracies acceptable to a wider stakeholder group.

It also enables recognition of the benefits of well-developed algorithms of satellite imagery to extract more robust seabed classification for habitat characterisation from the multispectral analysis. Notwithstanding the limitations of coverage with respect to depth and optical water clarity, habitat classification from SDB is at least on a par with similar modelling using MBES backscatter, interferometric sonar or bathymetric Lidar. There is logic to this supposition. A physics-based approach workflow, such as that developed by EoMap, aims to extract seabed reflectance as its primary result; in achieving that result, extraction of the water column (which we illustrate as water depth) is but an element of the process. Therefore, the algorithms associated with habitat mapping are not an addendum but fundamental to the entire imagery analysis effort. Coupled with other, higher-order survey data, however, SDB can also assist in creating hydrographic survey datasets that meet client specifications in a very cost-effective manner.

CONTINUED IMPROVEMENT

At the time of writing, the comparative analysis between SDB and the active sensor datasets is ongoing. The ability to mobilise multiple survey sensors from multiple platforms, acquire data from sensors that complement and reaffirm each other, and process data into a diverse range of data products and derivatives fulfils and surpasses the expectations of focused hydrographic surveying for nautical charting updates. It also offers results seminal for other applications derived from large-area baseline mapping. In the last decade, the hydrographic community has experienced the increased efficiencies of MBES surveys complemented with ALB for shallow-water and shoreline delineation. SDB furthers these gains by providing the information needed to plan safer and more cost-effective nearshore surveys.

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SEEING MORE FROM ABOVE

Growing Use of **Oblique Imagery** by Municipalities

For municipalities, aerial imagery is a vital support for geospatial and thematic information extraction and planning processes. Until recently, only orthophotos produced by nadir aerial images were used for this, but the development of oblique-image cameras is opening up new possibilities. Cases in 3D cartography, urban damage assessment and urban planning demonstrate the high value of these images and derived geospatial products.

Since the early 2000s, oblique camera systems have been used for well-known applications such as the visualisation of buildings, roofs and façades from a 360-degree perspective, realistic texturing of 3D city models and measurement of building heights in monoplotting mode. The inclusion of oblique images for the extraction of accurate 3D value-added products is also growing in importance today. That is made possible by larger sensor size, better radiometric and geometric resolution of the imaging systems, and the availability of new software solutions for image processing.

The immediate advantage of acquiring images from an oblique perspective is the possibility to view elements that are generally occluded in the vertical views by vegetation or higher structures; there is an additional perspective on objects such as road edges and lower building parts (Figure 1). Also, the determination of the vertical component of point ground coordinates is more accurate, due to a more stable stereo geometry. Another advantage is that the higher degree of image overlap, typical for oblique projects, favours dense point cloud generation and true-orthophoto production. Comparing 3D point clouds based on nadir images or Lidar sensors only to point clouds generated by nadir and oblique images proves that the latter are more complete. They model roof details, overhanging roofs, building façades, the front side of vertical elements or other features generally not visible in the nadir views. This explains the growing number of requests by municipalities for aerial photogrammetric flights using oblique cameras.

OBLIQUE IMAGING

Oblique aerial cameras consist of optical sensors, tilted with respect to the vertical direction, acquiring simultaneous images from different viewing perspectives. The most common camera design presents one photogrammetric nadir-viewing camera combined with four cameras tilted at an angle of between 30° and 50°, with forward-looking, backward-looking, left and right viewing directions.

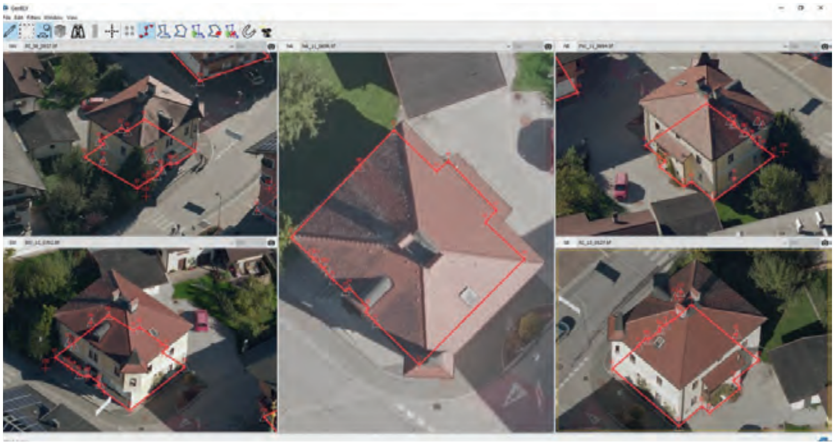
The Austrian company AVT and its subsidiary Terra Messflug have been operating oblique aerial flights with UltraCam Osprey cameras since 2015 for public and private customers. They share some of their experiences in this article.

COST-BENEFITS

An important question when proposing new technologies in smaller municipalities is, of course, the cost-benefit ratio. The costs of aerial photogrammetric flights with oblique cameras strongly depend on the settlement structure and the area to be covered, but are certainly higher than the nadir flights. That is due to the increased overlap between strips and the addition of a minimum of two strips on the borders for full oblique coverage of the area. Nevertheless, the employment of the oblique images can potentially reduce the field survey by the municipal staff and transfer part of the surveying operations to the office, if a proper measurement tool is available. At AVT, an Austrian company that operates oblique aerial flights with UltraCam Osprey cameras together with subsidiary Terra Messflug, flight strip overlaps are planned so that each object is captured on an average of six to ten images in each viewing direction. This ensures that there is almost always a recording that represents the object in question. Another important question is the usability. In smaller communities, geoinformation is often handled by staff whose main educational background or field of work is not GIS or surveying. This requires community geodata to be both easy to use and hard to abuse. Therefore, in addition to the aerial images themselves, municipalities need a tool to explore the images and carry out (3D) measurements with a user-friendly GUI and clear functionalities. To fulfil the

EACH OBJECT IS CAPTURED IN 6 TO 10 IMAGES IN EACH VIEWING DIRECTION

requirement for easy image visualisation and mapping, AVT – in cooperation with the Bruno Kessler Foundation research institute based in Trento, Italy – has developed software called 'Geobly'. AVT itself uses Geobly for high-precision oblique photogrammetric surveys.



▲ *Figure 1, Visualisation of a building in the Geobly software. The façade is visible in the oblique images, but not in the nadir one (centre).*

URBAN MAPPING AND MANAGEMENT

The added value of oblique imagery and Geobly lies in urban mapping and management, as demonstrated in the small town of Kundl in Austria. The town is located in an economically strong region, with a growing population and thus lively construction activity. In conjunction with the update of the cadastral information, the municipality decided to fly with an oblique digital camera and obtain – in addition to the standard photogrammetric products (i.e. digital terrain model, orthophoto, stereo plotting measurements) – comprehensive basic data for the civil authority, as well as a clearer presentation of all objects from several perspectives. The images were acquired with a ground sample distance of 5cm and oriented with aerial triangulation. Geobly was made available to the community of Kundl in order to measure metric information of interest at any time. A careful comparison of terrestrial measurements and measurements from the new tool validated the accuracy of the photogrammetric products.

'MORE ACCURATE VERTICAL POINT GROUND COORDINATES, DUE TO MORE STABLE STEREO GEOMETRY'

The town of Kundl uses oblique images for a number of applications: 1) In the civil department, all planned changes in the buildings are reviewed and documented, e.g. whether a carport or a patio is inadvertently laterally closed. In the past, a person was sent to document it on-site; 2) The analysis of the building structure as a basis for planning activities, and the determination of the number of floors and building heights (Figure 2), benefits the urban planners and building engineers; 3) The mapping of terrestrial and vertical traffic signs, which are very clearly recognisable in the images; 4) With respect to more efficient cartography and map updates, Geobly simplifies the recognition of the map elements by enabling the overlay of existing vector information (e.g. cadastral datasets) on the images. Based on this information the photogrammetric restitution from the oblique images at AVT is an integrated part of the map database update cycles; 5) In the fire protection assessment of industrial complexes and the neighbouring buildings, the oblique aerial images make it possible to check fire safety regulations and to determine escape and evacuation routes, to document suitable methods of entry, hard-standings and movement areas, etc. Back in the municipality office, it can therefore be quickly clarified whether the requirements are met; and 6) The town of Kundl plans to use the oblique imagery results for city planning purposes and location marketing in the preparation of virtual tours.

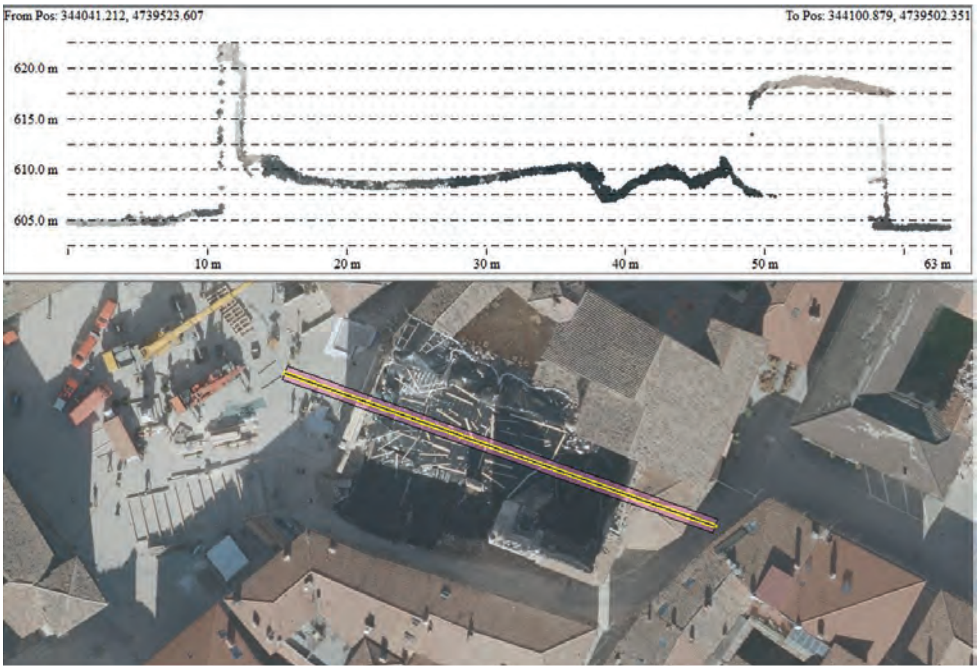
EARTHQUAKE DAMAGE ASSESSMENT

The use of oblique imagery was also very beneficial for the small town of Norcia, located in the central part of Italy. It was heavily damaged during the severe earthquakes in October 2016. AVT executed an aerial flight for the energy company Engie Italia, and acquired aerial images from five different viewing angles. A 3D model of the priority areas was generated and the local municipality was provided with a user-friendly tool for height and planimetric measurements. In this project a novel acquisition strategy for oblique imagery was successfully tested, based on the combination of a nadir camera with suitable focal length and a flight plan with two overlapping perpendicular blocks. The images were acquired with a ground sampling distance of 5cm (1 GSD). A dense image matching procedure (SURE, www.nframes.com) was applied in order to produce a 2.5D digital surface model (DSM), a 3D point cloud with a mean spatial resolution of 1 GSD, and a 3D mesh model at a resolution of 2 GSD. The interpolated 3D surface model of the damaged areas allowed the identification of the shapes of the buildings, the collapsed parts and the ruins on the ground in detail (Figure 3). Thanks to the oblique views of the historic area, even narrow alleyways were clearly visible in the images and could be modelled. A quantitative assessment of the damage was possible through measurement of distances, areas and volumes in the point clouds or measurement of building heights.

3D CITY MODELLING

Accurate 3D city models are a core element of modern urban mapping and represent an important source of information to support ▶

▲ *Figure 2, Mapping a building footprint.*



▲ *Figure 3, 3D point cloud of damaged buildings in Norcia and height profile along a section.*

various (smart city) applications, such as space management, energy assessment, 3D cadastre, noise and pollution propagation or disaster management. The Municipality of Bergamo, a city of about 120,000 inhabitants in northern Italy, requested an oblique image flight for the generation of a 3D city model of the historical centre (approx. 1.2 x 0.8km) that is situated on a hilltop. Surrounded by 16th-century Venetian walls, it features old mediaeval buildings with complex and varying shapes, located on narrow streets in a densely built-up urban area. In terms of 3D geometry mapping and modelling, this scenario poses significant challenges due to visibility constraints that limit data acquisition from an airborne platform. Historical buildings with complex roof shapes complicate the use of standardised primitive shapes. For this reason the flight was executed with high overlap between consecutive images of the same strip (i.e. 80%) and between adjacent strips (i.e. 60%). Starting from the images (10cm GSD) and the aerial triangulation results, the multi-view matching pipeline provided by SURE was adopted to extract a filtered 3D dense point cloud with a mean spatial resolution of 1 GSD (60 million points). Secondly, a 2.5D DSM cloud over the entire city was made and also a true orthophoto at 1 GSD resolution. To extract the 3D city model from the 3D point cloud, the CityModeller tool in the tridicon/Hexagon suite (www.tridicon.de) was adopted, with the building footprint, the 2.5D DSM cloud and an available digital terrain model (1m grid) as input data. Once the automatic modelling was complete, building models were edited in the 3D Editor tool. This tool allows the user to import oriented images, superimpose the generated building polygons over them and edit the geometry according to the 2D reference. Since obliquely oriented images can also be used as reference, the complete Bergamo dataset (nadir and oblique imagery) was adopted here to support the manual editing of the generated building models. This allowed for more convenient viewing directions to be exploited in checking and adjusting complex roof shapes and building outlines. The final 3D city model of the historic part of Bergamo will be used in the city's GIS environment (Figure 4).

COMMUNITY GEODATA ARE REQUIRED THAT ARE BOTH EASY TO USE AND HARD TO ABUSE

REMAINING NEEDS

Oblique aerial images enable an accurate, fast and clear recording of spatial data from within the office. The better identifiability of points (corners, roads, etc.) compared to vertical surveys has already proved its worth in municipalities. The interpretation of the image content is also easier for employees

▲ *Figure 4, View of the LoD2-compliant models of Bergamo reconstructed with the tridicon/Hexagon tools: an overview of the 3D scene within Google Earth (left) and a close-up view with colours corresponding to the building IDs provided by cadastral data (right).*

who are not practised in the daily use of orthophotos. But, of course, some customer needs and technological challenges remain. Recordings from different perspectives provide more information but also mean that large amounts of data are generated and processed. Therefore, there is a need for intelligent solutions for effective processing, management and interaction of big geospatial data. The widespread distribution of GIS in municipalities has also increased the demand for the inclusion of oblique image functionalities in a GIS environment in order to access all geospatial data in a single and familiar environment. With respect to the interoperability, the application software should be as simple as possible for professional and non-professional users, with the possibility to enter notes, sketches and symbols and export the information to standard file formats.

ACKNOWLEDGMENTS

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NEW THREAT AND OPPORTUNITY FOR PROFESSIONAL SURVEYORS

Digital Image Matching for Easy **3D Modelling**

Normally when something is too good to be true, it is not true. But in the case of digital image matching (DIM), professional surveyors should look twice – because their clients, and certainly those in the construction, infrastructure and 3D city mapping markets, certainly will.

Digital image matching (DIM) did not arrive like a bolt from the blue. It has been around in the photogrammetric world for the past two decades but, through further improvements to filter approaches and also thanks to optimal adaption of algorithms for surface interpretation and object reconstruction, the technique has been refined to generate photo meshes out of 3D point clouds. Now, it is possible to produce 3D mesh models, point cloud data, digital surface models (DSMs) and true ortho images as data products by processing source data – primarily imagery and/or laser-scanned point clouds. The imagery can be obtained from aerial surveys, unmanned aerial vehicles (UAVs or 'drones'), as well as ground-based mobile and static image capture using a variety of camera types, ranging from GoPro through to purpose-built air survey camera systems. Bentley is a prominent market player with its ContextCapture application which is being embraced by a growing number of companies, including Topcon recently. GIM International asked John Taylor, who is responsible at Bentley Systems for reality modelling in Asia Pacific and in the global defence market, for a peek inside the 'black box'.

PIXEL RESOLUTION

It is claimed that DIM makes it easy to produce 3D models using up to 300 gigapixels of photos taken with an ordinary camera, resulting in fine details, sharp edges and geometric accuracy. Getting straight to the point, Taylor is clearly very confident about the possibility of millimetre accuracy. "Accuracy will typically be twice the pixel resolution. The image sets need sufficient overlap, of course. Virtually any digital camera can be used. However cameras with larger sensors and high-quality lenses will provide more information, allowing for the potential of better results. It should be noted that data of differing resolutions can be processed into a single model, so model accuracies may vary depending on the geospatial extent of the source data used in the processing."

The process of creating a 3D model or point clouds in ContextCapture starts with adding images and/or point clouds as the data sources. When photos are used, the images are automatically aerotriangulated through a process of image comparison. This process automatically extracts tie

John Taylor: "Accuracy will typically be twice the pixel resolution."
John Taylor was educated at the Royal Military Academy Sandhurst and the University of Edinburgh, UK. He has an MSc in GIS. He is a qualified chartered surveyor and has a diploma in defence geospatial information management.

points, matches pairs and determines orientation and positioning of the block of images. “The aerotriangulation process can be computed entirely without control or camera positions, or else controlled using the camera’s positional metadata or surveyed control points,” explains John Taylor. The aerotriangulated block can then be processed into a 3D model. This process determines the exact extent for the resultant data, and sets the desired coordinate system and data formats. The process cleans up the point cloud and produces a triangulated mesh with a high geometric precision. The mesh is then textured from the photos using the best resolution from various photos used in this process.

ADDITIONAL DETAIL

The biggest output difference between ‘traditional’ digital photogrammetry and digital image matching software is the result. In standard photogrammetry, the result is usually a 2D product or perhaps a DSM, and most vector data products are an abstract of the source content. DIM uses a combination of photogrammetry and computer vision to create realistic 3D models in mesh or point-cloud formats. However, for survey managers, the single biggest difference might be the efficiency of the production process. “The automated aerotriangulation and resultant production of data outputs has minimal resource requirements,” Taylor affirms. “While the overall processes are similar, the difference lies in the huge number of images that can be automatically processed, using relatively low-cost computing resources, in a fraction of the time taken using a specialised digital photogrammetric workstation. Additionally, various parts of a scene can be captured using different cameras and at different resolutions to enable the production of multi-resolution data outputs.” The benefit of this is that large areas can be captured at a lower resolution (e.g. 5-10cm), and then specific parts of the scene (buildings, utility infrastructure, etc.) can be captured at higher resolutions (e.g. 1mm-2cm) to provide a wealth of additional detail, which could not be managed easily using traditional digital photogrammetry. Multiple jobs can be loaded, set up and left to process outside of working hours as part of a prioritised job schedule, which is particularly useful when multiple (as-built) surveys are being captured daily. Hybrid processing with laser scan data is also possible. “Laser scanning data does have advantages in low-light or night-time capture conditions, but can be noisy depending on airborne dust particles or moving objects in the scene during capture. Imagery clearly requires suitable lighting conditions (natural or artificial), but is less noisy in terms of processing. Being able to process both sources into a single model is clearly advantageous. Adding point cloud data is useful on any project where a combination of point clouds and photos are available. Our software will use the highest-quality data in these cases, making use of the points where they are dense and accurate and the photos where point data may be absent. It can also process laser scanning data into surfaces without imagery present, so there is some flexibility in how these data sources can be employed.”

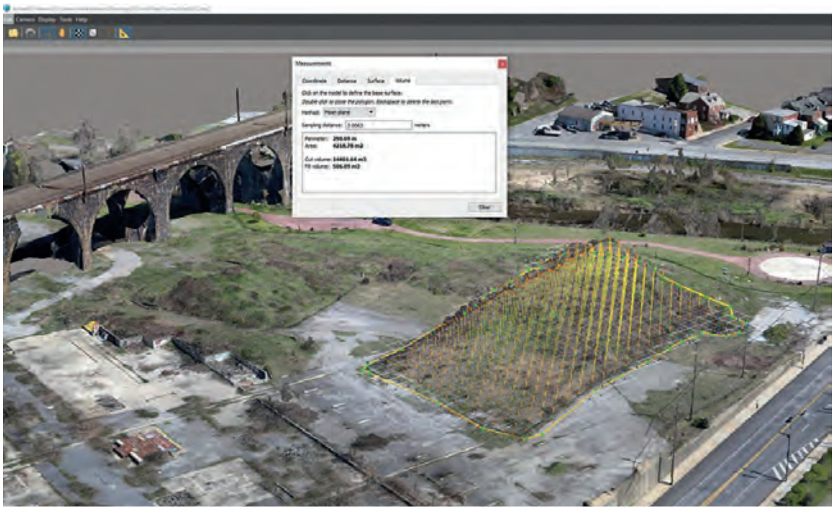
THE SURVEYING PROFESSION

When talking about ContextCapture, Bentley claims “You just need somebody with a camera”. On the other hand, the company names the surveying industry as a main target group. How can DIM be commercially attractive for the surveying professional rather than adding another nail to the discipline’s coffin? Taylor is convinced of the joint

LONDON BRIDGE STATION

Plans for London Bridge Station included reconstructing its concourse to include 15 new platforms, as well as establishing new retail stores and facilities. The Costain Group, which led the engineering project, needed an accurate 3D representation of the aging masonry structures to understand the subsurface for reconstruction potential. The model would also enable stakeholders to make better decisions on a tight schedule. While Costain previously used laser scanners to capture digital data to survey and document site conditions with precise accuracy, they now experimented with DIM. Using a simple camera to capture the old surface area delivered a denser survey than a scanner would, and also provided colour, enabling designers to quickly identify the bricks from the mortar joints. The project team then used ContextCapture to process the images into accurate 3D mesh models that facilitated decision-making and provided documentation of existing conditions that could be used throughout the lifecycle of the infrastructure. The use of DIM technology reduced the time it took to collect data and eliminated the process bottleneck associated with sharing a scanner among two dozen surveyors. Moreover, it streamlined workflows and improved design efficiency.

opportunities in surveying and engineering: "New value opportunities for surveyors are provided throughout the infrastructure lifecycle by 'continuous surveying'. That also goes for surveying in those complex situations where laser scanning has a much longer acquisition time and delivers a less dense survey while image interpretation is crucial." As an example, he takes the London Bridge Station project in the UK (see box on page 28). "Given the age of the structure at London Bridge Station and the logistical limitations of laser scanning – a process that would take too long to complete with one or two (more expensive) scanners – the engineers leveraged photogrammetry for the initial survey and regular updates. It was less disruptive to the on-site workers, given the speed and size of a small digital camera to survey the site. Those are new kinds of services to deliver by surveying companies. They themselves or the client can use DIM to process the images into accurate 3D mesh models to facilitate decision-making or provide as-built documentation."



▲ *In the survey of the 'The Flats' brownfield site, the Cedarville Engineering Group used 750 aerial photos and DIM to produce the 3D modelling and engineering plan in just four days.*

With regard to complex conditions, he also refers to a smart city project in the city of Coatesville, USA. An engineering group was tasked to provide 3D design and conceptual planning services as part of the city's 'The Flats' brownfield redevelopment, a rugged 30-acre former steel-mill site which contained hazardous materials. These conditions made it expensive (USD40,000) and potentially dangerous to perform a traditional on-site survey so the engineers decided to use aerial photos and DIM. They took 750 aerial photos in 20 minutes. It took 8 hours to produce a 3D engineering-ready model and three days for a final engineered plan, thus achieving a significant saving for the city.

THE SOFTWARE USES POINT CLOUDS WHERE THEY ARE DENSE, AND PHOTOS WHERE POINTS ARE ABSENT

DATA FORMATS

ContextCapture supports different software workflows within a single organisation, including a variety of CAD and GIS platforms. For those that fully embrace 3D, then the basic 3D mesh formats of OBJ, OSGB and Collada will often be supported by those systems as the formats have been around for some years. That is also the case for Esri, which has also chosen to develop its own 3D scene format, i3s; Bentley offers it as a standard export format. Specific CAD solutions are supported by formats such as Bentley's 3MX, 3SM and DGN and Autodesk's FBX formats. Additionally, as 3D GIS increasingly looks towards the web as the core delivery platform, Bentley has partnered with AGI to form the Cesium Consortium and to enable Cesium 3D tile export as standard. If the GIS still requires 2.5D data for analysis, ContextCapture provides editing capabilities that automate DEM extraction and then export the resultant DEM data to suit GIS import, either in text or Grid formats at user-selected data densities. Ortho images are another standard output that support GIS data needs, and for those systems that are point cloud capable then 3D data can be exported as an LAS point cloud file. ◀

E-PARTICIPATION OPPORTUNITIES IN KENYA

Public Participation Using **3D City Models**

The importance of involving the general public in the design of urban plans and development scenarios is widely recognised. Today's web technology and availability of 3D city models at various levels of detail enable local governments to communicate spatial plans effectively to their citizens. They also enable citizens to comment on and propose alternatives, thus providing feedback to local authorities. This means public participation is enhanced through e-participation. The authors investigate the opportunities offered by e-participation in Kenya.

Implementation of an urban development plan affects the lives of citizens residing or working in or near the area covered by the plan. The widening of an existing road will increase mobility but decrease liveability for the residents in the vicinity of that road. It is broadly recognised that citizens should have a voice in the planning of urban developments. The importance of citizens having a voice in plans which invoke environmental issues was recognised by the United Nations over 25 years ago and anchored in Principle 10 of the Rio Declaration of 1992 (see side bar).

E-PARTICIPATION

Web technology, 3D city models and 3D visualisation software can help in enhancing citizen feedback on spatial plans produced by authorities. Web technology eliminates the need for citizens to gather together at a certain place, at a particular moment; instead, individuals can choose how, when and where to participate, even anonymously if preferred. Furthermore, 3D visualisation of 3D city models stimulates the exchange of alternatives among stakeholders. In the developed world e-participation is increasingly being exploited to involve citizens in urban planning and management, but its use is still modest in developing countries. To demonstrate the feasibility of e-participation in developing countries, the authors created a 3D city model of Kisumu City, Kenya, which citizens can access via a web portal. Afterwards, experiments were conducted to measure the potential participation ability of six groups with different backgrounds, varying from the general public to professionals such as planners.

CREATION OF THE 3D CITY MODEL

The fundamental data for creating the 3D city model consisted of a digital elevation model (DEM), a GeoEye image acquired in 2009 with a ground sampling distance (GSD) of 50cm, and data provided by the city government. The satellite image

▲ *Figure 1, Part of the 3D model showing the Jomo Kenyatta Sports Ground, Kisumu.*

PRINCIPLE 10

At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

was draped over the DEM; the resulting geodataset acted as a foundation for creating the 3D city model. Shapefiles of the parcel boundaries, transport networks, administrative boundaries, building footprints and building heights – all data provided by the city government – were imported into CityEngine (2016) while keeping the geographical attributes from ArcGIS 10.4.1 intact. An LoD2 3D city model was generated by automatic texturing of LoD1 with image patches of building façades extracted from Google Earth. To give the final touch the model was manually edited (Figure 1). Next, the 3D model was visualised in a web portal provided by ArcGIS Online (http://arcg.is/2k68mrQ). This web-based 3D model was then used to test the suitability for e-participation. Participants could take part remotely, eliminating the need for town-hall meetings. Accounts enabled people to log in, view, navigate through and write comments. Opinions and alternatives were discussed during plenary workshops (Figure 2).

PARTICIPANT ABILITIES

To test how participants would experience and cope with the designed 3D model, two tasks were created: one related to 2D maps and the other to the 3D city model. In the 2D task participants received a 2D map on an A3-sized sheet of paper showing plot numbers and road networks and a list with ten feature names. Each participant had to select the name of a feature from the list, locate it and mark it on the 2D map within a time span of 10 minutes. In the second task participants carried out a similar task but now exploiting the 3D city model in a web-based geoportal instead. Their performance was measured in terms of the time needed to complete the tasks (efficiency), the number of correctly identified objects (effectiveness) and the participants' reflections on their experiences (satisfaction). The 37 participants were categorised in six groups (Table 1).

Figure 2, Student group at work with the 2D map during the workshop plenary.

Group	Males	Females	Total	Average age
Students	8	10	18	22
Planners	4	1	5	50
Surveyors	4	1	5	49
Architects	1	2	3	34
Engineers	2	0	2	33
Others	3	1	4	41
Total	22	15	37	36

Table 1, Characteristics of the various groups of participants.

RESULTS

Figure 3 shows a graph of the average time each of the six groups needed to complete the 2D task (blue bars) and the 3D task (orange bars). For all groups, the 3D task took less time than the 2D task. Experience plays a role: planners needed less time on average while students needed most time for both tasks. The 3D task resulted in more correct answers than the 2D task, but none of the groups managed to provide all the correct answers within the given time (Figure 4). With 53% correct answers, the students performed poorly in the 2D task, while engineers performed poorly in the 3D task. 83% of the participants preferred 3D over 2D.

Of course, the web portal can be improved and the participants' abilities are affected by some imperfections in the interaction with the web-based geoportal. The participants were able to view and navigate through the different objects and place comments. As mobile phones have a high penetration rate throughout the entire population in developing countries, e-participation using various web technologies – including smartphones, online forums and emails – could become the preferred approach.

CONCLUDING REMARKS

Participation does not necessarily mean that the public becomes part of all major decisions. Therefore, planning agencies should first define the issues and questions for which citizens' input is desired. Moreover, the participants' level of influence should

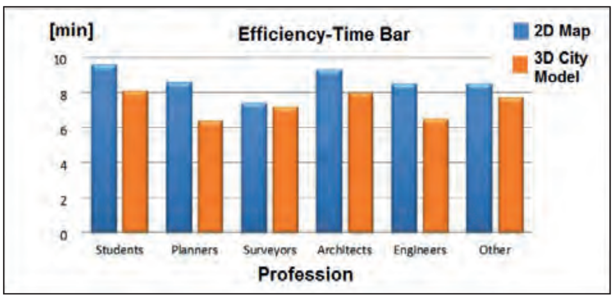


Figure 3, The time groups needed to complete the two tasks.

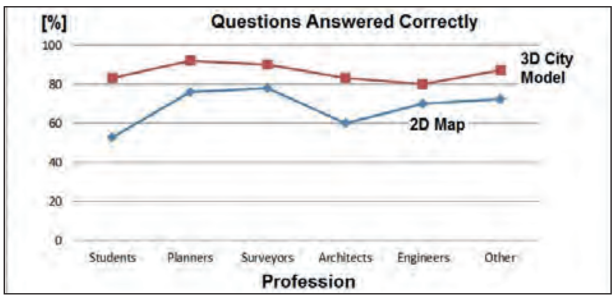


Figure 4, The number of correct answers per group.

be clearly communicated. These factors will all help to stimulate public participation and to define the roadmap. Future research will focus on the development of a stand-alone 3D web portal with full e-participation facilities. The addition of interactive facilities makes it more flexible and easier to use, enabling information exchange and learning. How users experience an e-participation tool depends on its complexity, its design and its purpose. Hence, such a tool cannot be developed without an explicitly defined application context.

ACKNOWLEDGEMENTS
Thanks are due to the City Government of Kisumu, Kenya, for providing data, to Dr Moses Kola, dean of the School of Planning and Architecture, for supporting the fieldwork, and to staff and students at ITC and Maseno University. ◀

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Video of the 3D city model: https://www.youtube.com/watch?v=wq_7IzPC9YE&feature=youtu.be

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GIM INTERNATIONAL INTERVIEWS DR FILIP BILJECKI

The Tough Road from 2D Maps to **3D City Models**

The demand for mapping intensively used parts of the Earth, including roads and cities, is steadily growing. This is because today's rate of urbanisation requires detailed and up-to-date geodata in its full three dimensions. Such datasets help city managers to prevent a decline in liveability, to limit water, air and noise pollution, and to improve fair taxation and rapid emergency response. Crucial is the abstraction of the 3D real world, a concept known as level of detail (LoD). Since 2012 Dr Filip Biljecki has been investigating how to improve the level of detail (LoD) in 3D city models. For his efforts – which were published in a hefty book called *Level of Detail in 3D City Models* – he recently received a PhD degree from Delft University of Technology. In acknowledgement of the high standard of his research, he graduated with the rarely awarded cum laude distinction, providing *GIM International* with reason enough to interview him.

What does level of detail (LoD) mean?

LoD is a key property of 3D city models and its concept is comparable to the scale of maps and the resolution of imagery. LoD is primarily related to semantic and thematic richness and geometric detail (see Figure 1). For example, LoD1 shows buildings as blocks with flat roofs, while LoD2 shows finer details, such as roof shapes and protrusions in the façades. A block model is perfectly suited for placing GSM antennas, while the optimal placing of solar panels requires shape, size and orientation of roofs. So LoD determines the usability of a dataset and has implications for its interoperability, maintenance and the conversion from the one data format into the other. Added to this, the geodata acquisition technique should allow the creation of the required LoD which goes hand in hand with costs.

Why would cities be interested in the creation of 3D models?

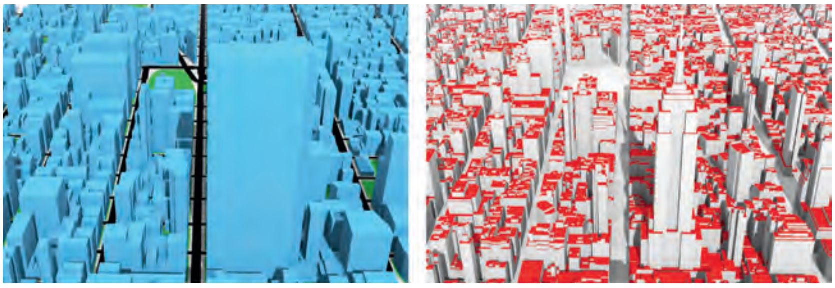
For the same reasons that they would be interested in 2D maps. 3D city models may be used for many applications. They offer additional insights when using traditional 2D GIS products or enable new applications. Let me give a few examples. Estimating the potential yield of solar panels placed on rooftops is impossible without 3D city models. Estimating noise pollution is more accurate when carried out on 3D models than on 2D maps (see Figure 2). This is because sound propagates through the air in all directions. Therefore, noise levels vary not only based on distance from the source but also based on elevation, which is not possible to account for when working in 2D. Such specialised applications of 3D city models, which often require substantial pre-processing of data, are interesting for city authorities as they improve their management tasks.

Isn't LoD just another term for abstraction and generalisation in surveying and cartography, and resolution in remote sensing?

Yes and no. Yes, because LoD has analogies with scale, generalisation, resolution and point cloud density. And no, because 3D city models differ from maps as they encompass metrics other than geometry, such as texture and semantic detail. For example, the geometry of buildings, described by their outlines, can be enriched with photo textures and additional information on, for example, year of construction. The geometric shape of roofs and the age of the building are key ingredients for predicting energy demand. To be honest, I'm not a fan of the term 'scale' in GIS due to its twofold meaning. First, it is related to paper maps, so the term is inappropriate for 3D city models which are usually in digital format. Second, scale has many meanings; large scale, for example, indicates a large spatial extent. The term 'resolution' is not suitable when dealing with 3D city models either. For imagery the term is okay as the resolution of a raster is homogeneous. 3D city models are different and heterogeneous; landmarks or parts of them (e.g. footprint versus roof), for example, may be modelled in different granularities. Discussions on terminology are inevitably subjective, and I'm sure that some colleagues will disagree with what I have just said. Terms have a historical background and often refer to technology which is fading out. As a consequence, terms developed in the heyday of paper maps are falling short now we're in the transition stage from 2D maps to digital 3D models.

One of the propositions accompanying your thesis reads: "There is no such thing as a general-purpose 3D city model". What does this mean and what are the consequences?

Practitioners and researchers use the term 'general-purpose 3D city model' to indicate seemingly generic datasets procured by cities and released as open data. This challenging proposition expresses that I am not fond of this term. A 2D dataset may be collected once and used for many purposes. Unfortunately the same does not hold true for 3D. Challenges include the fact that: requirements differ per application and software package; data formats are not fully interoperable; and thematic completeness is often lacking. In practice, the creation of one dataset that works with most if not all applications is troublesome and hence there is no one-size-fits-all 3D dataset. Of course, a dataset can serve several uses. An LoD2 CityGML dataset, for example, may be used for solar potential estimations as well as in urban planning, but it is too optimistic to assume that the same dataset would be suited for a wide spectrum of applications as is the case in 2D GIS. When designing specifications and acquiring data, companies and cities should focus on a set of intended applications of the 3D model, rather than on anticipating out-of-the-box uses for virtually everything.



▲ *Figure 1, 3D city models of Manhattan, showing a block model (left) and details of roofs and façades (courtesy: Chair of Geoinformatics at Technical University of Munich, and Department of Information Technology and Telecommunications (DoITT) of the City of New York).*

PROGRESS IN CREATING 3D CITY MODELS GOES HAND IN HAND WITH ADVANCEMENTS IN SENSOR TECHNOLOGY

Is it feasible to acquire or create a geodataset with a fine level of detail if the data gathering instruments have poor positional precision?

This depends on the application, but the general answer is no. Often, the improvements a fine LoD achieve do not outweigh the costs. The accurate computation of the volume of a building benefits more from a high positional precision than from fine detail. Coarse but highly accurate may thus result in higher quality than vice versa. However, there are always exceptions. In visualisation, which primarily aims at pleasing the eye, a fine LoD is preferred over high positional precision.

CityGML is an Open Geospatial Consortium (OGC) standard. What is your experience with the acceptance level of this standard?

Most 3D city models I've seen recently are available in CityGML. So it seems the standard is well adopted by the GIS community, including researchers as well as practitioners within local governments and companies. However, software adaptation is lagging behind – and CityGML is no exception, since familiarisation of a new standard in a community always follows a steep curve.

▲ *Figure 2, Noise pollution by a tram line simulated with Geomilieu-DGMR on data from City of the Hague and visualised in Blender; the red, orange and green contours represent high, medium and low noise pollution, respectively.*

The generation of 3D city models with a high level of detail is associated with high production costs. When and why should cities generate 3D city models with a fine LoD?
That's true, and the reason for high production costs is the same as for creating topographic maps and other 2D maps: manual labour is often prohibitively expensive. Production costs will gradually decrease, mainly because of further automation and augmentation of the details of a 3D city model by exploring architects' design rules instead of using actually acquired data. This process of artificial augmentation is called 'procedural modelling'. Whether it's worth producing a dataset at a fine LoD largely depends on its intended use. Data at a finer LoD may look attractive but, as I already said, the benefit may not always justify the costs.

A fine LoD contains dormers, chimneys and other roof details. Which applications require such a detailed reconstruction of shape, size and orientation of building features?
It's true that many applications do not need models with detailed roofs but may suffice with block models. That has been one of the topics of my research. That said, besides estimating the solar potential – which is one prominent use case requiring roof shapes – other applications may also benefit from LoD2 geometry. In the energy domain, roof shapes make it possible to differentiate attics and adjust the estimation parameters. Roof shapes may also support the fitting of indoor datasets and automated property valuation. In emergency response, knowing roof shapes can support advance action planning while first responders rush to the calamity site.

How do you see 3D city models evolving in relation to the ever-increasing capacities of (laser) sensors to acquire point clouds and the resulting ever-greater point densities?
Progress in creating 3D city models goes hand in hand with advancements in sensor technology and the capabilities of software to process the data. Until now, the creation of 3D city models has mainly focused on buildings rather than roads or bridges. Perhaps the increasing sensor and data-processing capabilities will result in 3D city models with improved thematic completeness. Improvements in sensor technology will also lead to finer LoDs and higher-quality datasets. If increasing capabilities are accompanied by decreasing acquisition costs, the creation of 3D city models may become easier, enabling more frequent updating. In other words, the higher the point density of point clouds is, the more 3D city models will benefit.

You published many scientific papers during your research at Delft University of Technology. What's your view on the 'publish-or-perish' mindset at universities?
First of all I think one should recognise that universities in general have two tasks: scientific research and teaching. With respect to scientific research, I support a publish-or-perish mindset because publication fosters scientific communication and forces researchers to share their work. Some researchers are reluctant to publish their work for various reasons, which is a pity because this impedes scientific progress. Added to this, I believe publicly funded researchers have the moral obligation to share their results, plus withholding or delaying results goes against the idea of science. Furthermore, publication usually initiates new contacts, triggers collaborative partnerships and prevents duplication of work, which is beneficial for all. On the other hand, the publish-or-perish paradigm impedes the teaching task. Staff are usually tasked with both research and education so the pressure to publish may curtail teaching efforts, possibly leading to reduced quality of education. ◂

PRESSURE TO PUBLISH MAY CURTAIL TEACHING EFFORTS, POSSIBLY LEADING TO REDUCED QUALITY OF EDUCATION

ABOUT DR FILIP BILJECKI

Filip Biljecki received an MSc degree (2010) and a PhD degree (cum laude) in 3D GIS (2017), both from Delft University of Technology, The Netherlands. His PhD research was supervised by Prof Jantien Stoter and Dr Hugo Ledoux. Filip is involved in the OGC, EuroSDR, ISPRS and other international collaborations. In 2016 the Austrian Academy of Sciences awarded him the Young Researcher Award in GIScience. In July 2017 he started as a research fellow at the National University of Singapore, working on the integration of BIM and GIS data.
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▲ *Dr Filip Biljecki amid members of his examination committee.*

FROM DIGITALISATION TO AUGMENTED REALITY

Surveying the World of Tomorrow

From 29 May to 2 June Helsinki, Finland – also known as a 'pearl of the Baltic Sea' – was the centre of the global surveyors' community during the FIG Working Week 2017. All participants were warmly welcomed by FIG colleagues in Finland. The programme was exciting and future-oriented.

FIG Honorary President Juha Talvitie, who was president of FIG in 1990 (the last time the FIG Working Week was held in Helsinki) gave a short and inspiring welcome address greeting all the younger surveyors and also those who had attended in 1990. FIG President Potsiou began her opening address by stating: "Finland is a top performer in numerous metrics of national performance, including education, economic competitiveness, civil liberties, quality of life and human development, and our Finnish colleagues, top professionals, have chosen an appropriate theme for this Working Week for the times in which we are living."

CHANGE

President Potsiou further stated that change continues, as it always has and always will, inexorably. Change in the surveyor's world is not limited to technological invention. Systems and processes are just as growth-oriented as the hardware that we use. The formation of FIG in 1878 was the beginning of the globalisation of our profession. First it was the organisation representing surveying associations of a mere seven western European countries; today it represents over one hundred. Nowadays, modern globalisation is being questioned for its fairness and efficiency yet we feel its effects on our profession.

SIBELIUS

Finlandia, by Jean Sibelius, symbolically accompanied by breathtaking photos of the Northern Lights and the subsequent sunrise, was an emotional conclusion to the Opening Ceremony. The sun then also rose over the Working Week with its myriad of activities, sessions, meetings and networking possibilities plus a lively exhibition showcasing new technology and equipment and stimulating new thinking.

GOOGLE

The presentation by Ed Parsons, geospatial technologist and tech evangelist at Google, was of the highest level. He explained how, from the perspective of users and consumers, the benefit of geofunctionality is in the details: 'avoid the traffic, 'get me home' and 'eat out' are well-known examples, as is 'never lost'. He stated that a new generation of digital natives is on its way, who will combine big data to egocentric scales. There will be more and more simultaneous localisation and mapping – thus creating digital reality.

KEYNOTES

All keynotes were a source of inspiration and very much in alignment with the theme of the Working Week: 'Surveying the World of Tomorrow'. Arvo Kokkonen from National Land Survey Finland questioned whether the surveying sector is changing quickly enough. He concluded by predicting a future with "many players in the field" as land information will become increasingly recognised as part of the basic infrastructure. Greg Bentley from Bentley Systems gave a fascinating keynote on 'Going digital: reality modelling advances surveying, and engineering'. According to Greg, reality modelling is going mainstream and 'conceptioneering', 'constructioneering', 'inspectioneering' and 'productioneering' are all underway. Oumar Sylla from Global Land Tool Network highlighted in his keynote the relevance of land information as a key ingredient for achieving the Sustainable Development Goals. Tenure security for all is one of the goals in which surveyors worldwide play a vital part. Robert Guinnes, Finland, shared details of future trends in pervasive

During the Opening Ceremony, FIG President Potsiou reminded all participants that "the formation of FIG in 1878 was the beginning of the globalisation of our profession…Today, modern globalisation is being questioned for its fairness and efficiency yet we feel its effects on our profession."

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▲ *President Potsiou with national delegates at the Working Week 2017, which was attended by 90 countries.*

▲ *The exhibition was well attended both by local and international exhibitors. The Turkish delegation had a vibrant stand promoting the FIG Congress 2018.*

positioning, saying that accuracy, availability and reliability of GNSS will increase. Yola Georgiadou from ITC, Twente University, made a brilliant contribution on geoethics. Jolyne Sanyak from Landesa presented on 'How can we favour secure land rights for the digitalised world we want?'. She explored innovative and more affordable technology and how to democratise data gathering. Markku Poutanen went back to the roots with a very interesting overview of the future of reference frames. Fredrik Zetterquist wondered whether we are embracing the global transformative forces, with a showcase of cadastral procedures conducted by citizens.

POINT CLOUDS

The most provocative keynote came from Juha Hyyppä, the director of remote sensing and photogrammetry at the Finnish Geospatial Research Institute, with his presentation titled 'Disruptive technologies threatening national mapping and cadastral agencies' centralised mapping'. He said that, over the next two decades, new mobile laser scanning systems will make laser scanning ubiquitous. Even autonomous robots using point-cloud-generating perception sensors may be added to the ecosystem during this time frame. Juha is convinced that during the 2020s and 2030s, a great number of laser scanners will become omnipresent in everyday life. Mobile laser scanning is also one of the main techniques to create local virtual reality. Physical and virtual worlds will be merged. His presentation illustrated many examples of where cadastre is missing, even if the use of imagery is promoted in that area. He proposed action items including a national topographic database with high-quality point clouds and images. "Change or die" was his final message…

HISTORY SYMPOSIUM

Prior to the FIG Working Week, the International Institution of History for Surveying and Measurement – one of the permanent institutions of FIG – hosted a one-day symposium. There were several contributions from the Nordic countries and also from Serbia, Canada and Croatia. The Struve Geodetic Arc and the Enhancement from North Cape to Cape Agulhas in South Africa – the Longest Meridian on Earth were presented as highlights in geodesy. The contributions on the surveyors in the Roman Empire were fascinating. FIG Vice President Mikael Lilje brought along two books by Swede Martin Ekman on Celsius and 500 Years of Nordic Mapping.

BIM FOR SURVEYORS

Another pre-conference event was on BIM for surveyors, which attracted more than 50 professionals and academic engineers from 27 countries. Building information modelling (BIM) is the key for the implementation of digital models and processes for the construction industry. The workshop showed that surveyors play a crucial role in BIM design and implementation: managing project and asset data with proper coordinate reference systems, linking the construction project to GIS, measured surveys of the built environment using terrestrial laser scanners, setting out and machine guidance, linking virtual building models to land management, tendering and costs. Surveyors make BIM work properly.

YOUNG SURVEYORS NETWORK

The success of the FIG Young Surveyors Network (YSN) and its previous events has paved the way for yet another collaboration of young students and professionals; YSN organised its Fifth FIG Young Surveyors European Meeting and various sessions within the overarching FIG Working Week. Merging those two events allowed young surveyors from all over the world to participate in and experience the full range of FIG events and activities. The atmosphere was energetic, and the participants shared news and reports on their activities, research and work. The highlights were actively shared through the YSN social media channels, allowing young surveyors across the globe to join in and interact.

PROGRAMME

The FIG Working Week 2017 attracted about 1,400 participants from 90 countries worldwide. The programme included 400 papers presented in 57 sessions. There was a series of 'inspirational sessions' with short presentations and a focus on debate and discussion. The FIG Platinum Members – Trimble, Bentley Systems, Esri and Leica Geosystems – gave spectacular overviews of their services. The city of Helsinki, with its unique climate, beautiful evening lights and relaxed atmosphere, helped to make the event unforgettable. FIG thanks its Finnish colleagues for this experience! ◀

▲ *Participants just before the start of the Charity Run, organised by the Young Surveyors.*

Record Number of FIG Member Associations at FIG General Assembly

As part of the FIG Working Week 2017 that took place in Helsinki, Finland, the General Assembly was held on 29 May and 2 June. A record number of member associations – 73 altogether – were present on one or both of the days. Together with other members and observers, around 350 delegates attended the General Assembly in total.

In her report on the past year, FIG President Chryssy Potsiou stated that it was hard to include all the many activities that have been going on and all the volunteers who have been involved and have done such substantial work for FIG: activities including the council, the 10 commissions, networks, permanent institutions and the current task forces. Together they are all striving for one goal: to increase the value of FIG's data, tools and services for society.

Two new Honorary Members and an Honorary Ambassador were appointed. Daniel Steudler from geosuisse is well known all over the world for his extensive work for FIG since 1994. Among other things he has worked on the Cadastre 2014 publication, implementation and maintenance of the Cadastral Template (which was last year updated to Version 2.0), as chair of the Task Force on Spatially Enabled Societies and on the publication Cadastre 2014 and Beyond.

The Presidents' Meeting with all the presidents/heads of representation.

Yerach Doytsher has likewise been involved in FIG activities since the 1990s and has, among other things, served as FIG commission 3 chair, chair of the Task Force on Scientific Journal, ACCO representative to the FIG Council, and a key member of the Local Organising Committee for FIG Working Week 2009. Paul Munro-Faure, formerly of FAO, received a special appreciation as FIG Honorary Ambassador for his work at FAO in cooperation with FIG over many years, especially on the development and implementation of the Voluntary Guidelines (VGGT) around the world. He has also served FIG as commission 7 chair.

The competition between Krakow (Poland) and Accra (Ghana) to become host of FIG Working Week 2021 was intense. The member associations from both countries were well prepared and original in promoting their applications. It was a close-run decision, but Accra (Ghana) won the vote in the end.

Louise Friis-Hansen, FIG director

More information
www.fig.net

Creating a Global Index of National Spatial Data Infrastructures

The need for an integrated agenda across the environmental, economic and social sectors is encapsulated in the UN Agenda 2030 through the Sustainable Development Goals (SDGs). Spatial evidence is required to monitor and assess progress towards a large proportion of the goals. To achieve this, a country needs to have the underpinning and supporting infrastructure to allow spatial data to be accurate, transparent, open and interoperable – something that a National Spatial Data Infrastructure (NSDI) can help to achieve. Despite this, there is currently neither an available global measure of a country's NSDI to perform these functions, nor a way to identify where improvements need to be targeted.

The GSDI project to create a global index of NSDIs proposes a set of indicators to score NSDIs globally. The index consolidates and condenses a large body of scholarship and experience on NSDIs into a set of key components that can be assessed and benchmarked using six indicators. The index will provide a top-level, multi-actor assessment and is intended to both support and stimulate more detailed assessments for regions of the globe where strong transnational planning capacity is vital and urgent for users.

The NSDI index is being executed by Georgina Chandler, with assistance and supervision from Prof Joep Crompvoets (KU Leuven), Paul Jepson (Oxford University), Susanne Schmitt (World Wildlife Fund-UK) and Dave Lovell (GSDI president-elect).

The index will be pilot tested on a selection of 10-15 countries and the results, along with the proposed index, will be published and

presented in an academic paper. The index will be rolled out globally using an online platform hosted on the GSDI website. The results, without weighting, analysis or conclusions being drawn, will be made available as an overall averaged score from all respondents to give the index value for each country.

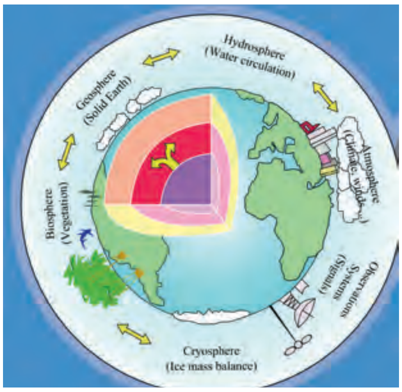
Ultimately, the scoring that a comprehensive and stakeholder-relevant index provides will allow investment and decision-making to be directed towards any weak or problematic areas of NSDI development. It will promote collaboration between government departments and other stakeholders and will motivate them to improve their spatial data quality, management and availability. There is also the potential for the index to raise awareness of potential barriers to a country effectively reporting spatial data evidence to the Sustainable Development Goals and other international agreements.

For further information, contact Georgina Chandler at: georgiechandler@gmail.com.

More information
www.gsdiassociation.org
www.geocat.net

The Global Geodetic Observing System, Revisited

GGOS is the Observing System of the International Association of Geodesy. GGOS works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system. GGOS supports and encourages the integration of different geodetic techniques, different models and different approaches in order to ensure long-term, precise monitoring of the geodetic parameters associated with the Earth's shape, the Earth's gravity field and the Earth's rotational motion. GGOS therefore provides

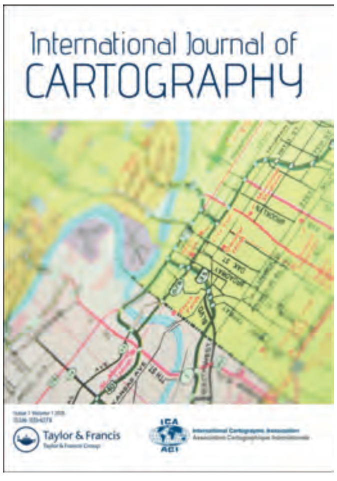


the observational basis to maintain stable, accurate and global reference frames crucial for geoscience as well as for many practical geospatial applications. GGOS also has an advocacy role, and acts as the interface between the geodetic services and external users such as the Group on Earth Observation and various United Nations authorities.

GGOS leadership is provided by a chair and a vice-chair, who liaise with the GGOS Consortium (which serves as the steering and election committee). These are supported by the GGOS Coordinating Board (the decision-making body) and the GGOS Executive Committee (the management board). In turn, all leadership elements work in concert with the IAG Scientific Services. The GGOS Coordinating Office supports outreach, internal and external coordination and the daily management of GGOS.
At the heart of GGOS are its bureaus. The Bureau of Networks and Observations contains working groups on satellite missions, simulations and data and information systems. The Bureau of Products and Standards oversees working groups on Earth system modelling and standards, and on promoting the development of new geodetic products associated with the three GGOS focus areas: Unified Height System, Geohazards Monitoring, and Sea Level Change.

More information
www.ggos.org

A Journal of Progress



The first issue of the International Journal of Cartography.

The ICA column in the February 2015 issue of *GIM International* announced the establishment of the *International Journal of Cartography* (IJC), an ICA initiative allowing the international research, education and professional community to report and disseminate the outcomes of its wide field of endeavours. It aims to promote research, ideas, outreach, developments and industry to all who work in cartography and GIScience. ICA sees this partnership, and the provision of a quality international peer-reviewed journal, as an important tool for its goal of advancing cartography and GIScience. This month's column reports on the significant progress in the maturing of this publication.
IJC has two co-editors (William Cartwright and Anne Ruas), four distinguished associate editors (Elri Liebenberg, Gennady Andrienko, Lynn Usery and Zhilin Li) who act as key partners in growing the journal into a key international research publication, and an Advisory Board with a mix of established and emerging researchers who assist in reviewing papers and provide general input into the journal's development. IJC aims to reflect all areas of the ICA research, teaching and professional communities' expertise and in so doing to define contemporary cartography and GIScience. The journal covers activities in these fields: traditional, transitional and visionary.

All submissions and reviewing for papers are handled electronically through IJC publisher Taylor and Francis' online facility, managing the paper-handling process from submission, through review and revision, to publishing. Papers are double-blind reviewed and then published speedily online initially, with a print version published when complete. Abstracts in English and French supplement papers, with a third abstract in the authors' mother tongue possible. Both ICA and the publisher are committed to actively promoting IJC and ensuring that positive actions are taken to gain a high index rating as quickly as possible.
The first issue was published in the first half of 2015, containing eight selected papers from the 2015 International Cartographic Conference held in Rio de Janeiro, Brazil, plus an editorial. Issue 2 for 2015 contained six papers. Volume 2, 2016 also had two issues, the first (guest edited by Georg Gartner and Haosheng Huang) selecting papers from the European Symposium on Cartography held in Vienna in November 2015; these provide insight into research activities of European colleagues. Issue 2 contained six papers plus an editorial. Similarly, two issues are being published in 2017, the first with selected papers from the International Cartographic Conference 2017 in Washington D.C., including an editorial by Mike Peterson. Issue 2 is a Special Issue on Research, with papers being the formal outcomes from the ICA/Esri Cartographic Summit of 2016. The editorial team for this edition is led by Amy Griffin.
IJC will grow to three editions in 2017, and special editions on Standards and Risk, Generalisation, and the History of Cartography are planned. The editorial board actively invites paper submissions through the IJC website at www.edmgr.com/tica/ and there is more current information about IJC at http://www.tandfonline.com/toc/tica20/current with access to the contents.

More information
www.icaci.org

ISPRS Geospatial Week 2017 Taking Shape

The ISPRS Geospatial Week 2017 (ISPRS GSW 2017, http://gsw2017.3snews.net) will be held in Wuhan, China, from 18-22 September 2017. This third ISPRS Geospatial Week will be organised by Wuhan University and will be the most important ISPRS event this year. The scientific steering committee of GSW 2017 is now ready and ten workshops will take place during GSW 2017. The topics of the ten workshops cover geospatial information acquisition, extraction from point clouds, optical/SAR imagery and ubiquitous sensors, smart city and global changes, geospatial information mining and quality control, indoor 3D mapping and navigation, and UAV/UAS innovation applications. Many international geospatial companies such as PCI will show their latest geospatial technologies and solutions at this great event. The details of the ten workshops can be found at: http://gsw2017.3snews.net.

Deren Li.

The six plenary speakers at GSW 2017 come from Europe, North America and Asia and are all approved by the ISPRS council. The submissions have closed and the first round of reviewing is finished as well. ISPRS GSW 2017 received around 500 submissions in total from more than ten countries. Approximately 300 submissions have been accepted as oral or poster presentations. The local committee and the workshop chairs are busy with preparing the preliminary programme of ISPRS GSW 2017 and it is scheduled to be published by mid-July. With a colourful five-day scientific programme, people from geospatial academia and industry will be able to share research ideas, present their latest research achievements and discuss possible collaborations. It will be an excellent opportunity for you to meet with top scientists, experts, researchers and users in the field of photogrammetry, remote sensing and spatial information sciences. A number of awards and competitions will also be organised during ISPRS GSW 2017, including awards for best papers and best posters as well as benchmark competitions. Several technical/industrial exhibitions will be organised, which will present the advances of new geospatial technologies and solutions (e.g. smart cities, UAV/UAS).
On behalf of the ISPRS council, I would like to invite you to join us at ISPRS GSW 2017. You are warmly welcome to visit Wuhan and China this September!

Prof Deren Li

More information
www.isprs.org
www.acrs2017.org

2017

JULY

INTERNATIONAL CARTOGRAPHIC CONFERENCE
Washington, USA
from 2-7 July
For more information:
icc2017.org

ESRI USER CONFERENCE
San Diego, USA
from 10-14 July
For more information:
www.esri.com/events/user-conference

CLOSE RANGE SENSING TECHNIQUES IN ALPINE TERRAIN
Innsbruck, Austria
from 16-22 July
For more information:
www.uibk.ac.at/geographie/summerschool

FOSS4G-EUROPE
Marne la Vallée, France
from 17-22 July
For more information:
europe.foss4g.org

SEPTEMBER

UAV-G 2017
Bonn, Germany
from 4-7 September
For more information:
uavg17.ipb.uni-bonn.de

CMRT17 - CITY MODELS, ROADS AND TRAFFIC
Hannover, Germany
from 6-9 september
For more information:
www.ipi.uni-hannover.de/hrigi17

ISPRS GEOSPATIAL WEEK
Wuhan, China
from 18-22 September
For more information:
zhuanti.3snews.net/2016/ISPRS

INTERGEO
Berlin, Germany
from 26-28 September
for more information:
www.intergeo.de

OCTOBER

GEOMATIC AND GEOSPATIAL TECHNOLOGY ASIA 2017
Johor Bahru, Malaysia
from 4-5 October
For more information:
www.geoinfo.utm.my/ggt2017

ESRI EASTERN AFRICA USER CONFERENCE
Dar es Salaam, Tanzania
from 4-6 October
For more information:
www.esriea.co.ke/user-conference-2017

RACURS CONFERENCE - FROM IMAGERY TO DIGITAL REALITY
Hadera, Israel
from 16-19 October
For more information:
conf.racurs.ru/conf2017/eng

CALENDAR NOTICES
Please send notices at least 3 months before the event date to: Trea Fledderus, marketing assistant, email: trea.fledderus@geomares.nl

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